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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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See half-page Advert. last week and next week. 1382

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See Advertisement last week, page 86.

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See page 17. 1134

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See Advertisement, page 71, April 13.

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See their Illus. Advertisement, page 93, last week.
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See Advertisement Page 57. 1111

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819

Matthew Paul & Co., Ltd.,
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See Full Page Advt., page 50, March 30.

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For Production of SHEET METAL WORK, COINAGE, CARTRIDGES AND GUNPOWDER.
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See half page advert., page 82, March 30. 8195

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See Advertisement page 56. 2402

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See half-page Advertisement, page 63, April 13.

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For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, Mount Street, Manchester.

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COWPER-COLES, S.C. PATENTS.

Notice is Hereby Given that

all PATENTS provisional or otherwise, standing in this name, and all processes, inventions, existing and future, are the PROPERTY of METALS REPRODUCTION, Ltd., 40, Grosvenor Place, and no one has any authority to deal with them except through the Company.

FRANK DE F. ENGLAND,
Secretary-Director. A 213

IN THE HIGH COURT OF JUSTICE. No. 00611 of 1922.
CHANCERY DIVISION,
MR. JUSTICE P. O. LAWRENCE
IN THE MATTER of ASSOCIATED FIRE ALARMS LIMITED AND REDUCED
and
IN THE MATTER of THE COMPANIES (CONSOLIDATION) ACT, 1908.

Notice is Hereby Given that

a Petition for confirming the reduction of the capital of the above named Company from £160,000 to £60,000 was on the 8th day of March 1923, presented to the High Court of Justice and is now pending. A list of the persons admitted to have been creditors of the Company on the 10th day of April 1923 (the date fixed by the Order in this matter dated the 17th April 1923) may be inspected at the offices of the Company at Jewin House, Redcross Street, in the City of London or at the office of Hair & Co. at 1, Cornhill, in the City of London (the Company's Solicitors) at any time during usual business hours, on payment of the charge of one shilling.

ANY person who claims to have been on the 10th April 1923 and still to be a creditor of the Company, and who is not entered on the said list and claims to be so entered must on or before the 2nd day of May 1923 send in his name and address, and the particulars of his claim, and the name and address of his Solicitors (if any) to the undersigned at 1, Cornhill, in the City of London, or in default thereof he will be precluded from objecting to the proposed reduction of capital.

DATED this 17th day of April 1923. A260
HAIR & CO.,
Solicitors to the said Company.

Crystal Palace School of PRACTICAL ENGINEERING.

Founded 1872.

Principal.—J. W. WILSON, M.I.C.E., M.I. Mech.E. The New Course will commence on May 2nd, new students enter on the morning of MAY 1st. A251

Correspondence Courses for

Inst. Civil Engrs., Inst. Mech. E., London Univ. (Matric., Inter., B.Sc.), and ALL ENGINEERING EXAMINATIONS personally conducted by Mr TREVOR W. PHILLIPS, B.Sc. (Honours), Assoc. M.Inst.C.E., M.R.S.I., F.R.S.A., &c. Also Day Tuition in Office. Excellent results at all Exams. Courses may commence at any time, and all Students receive individual tuition.—For full particulars apply to 8/11, Trafford Chambers, 58, South John Street, LIVERPOOL. 1295

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and SALES MANAGEMENT.—Write for brochure describing our special Course of training for posts of unlimited scope in this lucrative field.—DIRECTOR, Institute of Engineering Salesmanship, 333, Oxford Road, Manchester. 1401

TENDERS.

COUNTY BOROUGH OF SALFORD.

Tenders are Required not

later than 12 noon, Wednesday, 2nd May, 1923, for FOOTBRIDGE over River Irwell at Gerald Road.

CONTRACT No. 1.—Masonry, Concrete Steps, Concrete and Rock Asphalte Bridge Flooring and Street Works.

CONTRACT No. 2.—Steelwork.

Specifications and Quantities from Borough Engineer, Town Hall, Salford, on payment of a deposit of £2 2s. for each Contract, which will be returned on receipt of a *bona fide* Tender.

L. C. EVANS, Town Clerk. A 236

DEPARTMENT OF PUBLIC WORKS,
Sydney, 31st January, 1923.
SYDNEY HARBOUR BRIDGE TENDERS—EXTENSION OF TIME.

Tenders are Invited by

the Government of New South Wales for the CONSTRUCTION OF THE SUPERSTRUCTURE AND SUBSTRUCTURE OF A CANTILEVER BRIDGE ACROSS SYDNEY HARBOUR FROM DAWES POINT TO MILSON'S POINT, embracing a main span of 1650 feet in the clear, centre to centre of main piers, and a length of main bridge 2640 feet centre to centre of anchor piers. The total length of main bridge and approach spans included in tender is 3810 feet; also an ALTERNATIVE TENDER for the CONSTRUCTION OF THE SUPERSTRUCTURE AND SUBSTRUCTURE OF AN ARCH BRIDGE ACROSS SYDNEY HARBOUR FROM DAWES POINT TO MILSON'S POINT, embracing a main span of 1650 feet in the clear centre to centre of bearings. The total length of main bridge and approach spans included in tender is 3770 feet. Either bridge is to provide for four lines of railway, six lines of vehicular traffic, and footway accommodation.

Copies of Specification, including Plans, Technical Information, General Conditions, and Tender Forms, may be obtained by *bona fide* tenderers on application to the Under Secretary for Public Works, Sydney, or to the Agent-General for New South Wales, Australia House, The Strand, London; the Minister of Railways and Canals, Ottawa; The Australian Trade Commissioner in the United States, New York; or the Bureau of Foreign and Domestic Commerce, Washington, D.C., United States.

Tenders, the time for which has been extended, must reach the Under Secretary for Public Works Sydney, New South Wales, not later than 30th November, 1923.

R. T. BALL, A 59
Minister for Public Works and Railways.

CLYDE NAVIGATION.

TO SHIPBUILDERS.

GRAB-HOPPER DREDGER.

The TRUSTEES of the CLYDE NAVIGATION invite

Tenders for a Grab-Hopper

DREDGER, 188 feet long overall, 35 feet breadth moulded, and 16 feet depth moulded.

The Specification and Form of Tender, along with Drawings, may be obtained on application at this Office to Mr. Daniel Fife, Mechanical Engineer, on payment of a fee of £3 3s., which will not be returned.

Sealed Tenders, marked "Tender for Grab-Hopper Dredger," require to be lodged with the undersigned not later than noon on Monday, 21st May.

The Trustees may not accept the lowest or any Tender.

T. R. MACKENZIE,
General Manager and Secretary.
16, Robertson Street,
Glasgow.
13th April, 1923. A 224

CITY OF LINCOLN.

TO WATERWORKS ENGINEERS, CONTRACTORS, MACHINERY BROKERS, &c.

The Waterworks Committee of the Council is open to receive

Offers for the Purchase and

REMOVAL of the whole or part of the DISUSED PUMPING MACHINERY as it now stands at the Old Waterworks, Boultham, Lincoln, comprising Two Cornish Beam Pumping Engines and a pair of Horizontal Worthington Pumping Engines, together with all steam and water piping, valves, overhead cranes, winches, &c.

Schedules and permission to view may be obtained from the undersigned, to whom Tenders must be sent addressed to the Chairman of the Waterworks Committee endorsed "Tender for Machinery," not later than Wednesday, the 16th day of May next.

The highest or any Offer will not necessarily be accepted.

CHARLES HOROBIN,
Waterworks Engineer.
Saltergate,
Lincoln.
16th April, 1923. A 247

SOUTH STAFFORDSHIRE WATERWORKS COMPANY,
SANDFIELDS PUMPING STATION,
LICHFIELD.

TENDERS FOR DISMANTLING PLANT.
CONTRACT No. 3.

The Chairman and Directors are prepared to receive

Tenders for the Purchase,

DISMANTLING and REMOVAL of THREE FLYWHEEL BEAM ENGINES and TWO LANCASHIRE BOILERS at their Sandfields Pumping Station, Lichfield.

Copies of Conditions of Contract, Specification and Form of Tender with Permit to visit Station may be obtained from the undersigned.

Sealed Tenders addressed to me and endorsed "Tender for Dismantling Plant, Lichfield," must be delivered not later than Ten a.m., Monday, the 7th of May, 1923.

The Chairman and Directors do not bind themselves to accept the highest or any Tender.

FRED. J. DIXON, M.Inst.C.E.,
Engineer.
Engineer's Offices,
28a, Paradise Street.
Birmingham.
17th April, 1923. A 268

TO HEATING ENGINEERS AND OTHERS.

THE METROPOLITAN ASYLUMS BOARD invite

Tenders for the Installation of

FORCED CIRCULATION HEATING AND HOT WATER SUPPLY APPARATUS, CENTRAL KITCHEN PLANT AND SUNDRY ALTERATIONS TO COLD WATER AND GAS SERVICES AT THE DOWNS HOSPITAL FOR CHILDREN, BANSTEAD ROAD, SUTTON, SURREY, in accordance with Drawings and Specification prepared by Mr. T. Cooper, M.Inst.C.E., M.I.Mech.E., Engineer-in-Chief. The Drawings, Specification, and Form of Tender may be inspected at the Office of the Board, Embankment, E.C. 4, on and after Ten a.m. on Monday, 23rd April, 1923, and can then be obtained upon payment of a deposit of £3 3s. 0d. The amount of the deposit will be returned only after the receipt of a *bona fide* Tender sent in accordance with the instructions on the Form of Tender and after the Specification and the Drawings have been returned.

Tenders addressed as noted on the form must be delivered at the Office of the Board not later than 2.30 p.m. on Wednesday, 23rd May, 1923.

(By Order) G. A. POWELL,
Clerk to the Board.
A 244

STATE ELECTRICITY COMMISSION OF VICTORIA.

AUSTRALIA.

Tenders are Invited for

the MANUFACTURE, SUPPLY, DELIVERY and SUPERINTENDENCE of ERECTION of the following:—

SPECIFICATION No. 23/63.

ELECTRICALLY OPERATED POWER SHOVEL.

Tender forms, Specification, Contract Conditions, etc., are available upon application to

AGENT-GENERAL FOR VICTORIA,
Melbourne Place, Strand,
London, W.C. 2.

The charge per one set of two copies of the Specification is £1 which will be refunded on receipt of a *bona fide* Tender and the return of all documents supplied.

Tenders on prescribed forms accompanied by a deposit of £50 and endorsed "SPECIFICATION 23/63 — ELECTRICALLY OPERATED POWER SHOVEL," will be received up to Noon on the 31st July, 1923, by

R. LIDDELOW,
Secretary,
State Electricity Commission of Victoria,
23-32, William Street, Melbourne.

The Commission does not bind itself to accept the lowest or any Tender. A 253

THE DIRECTOR-GENERAL, INDIA STORE DEPARTMENT, Branch No. 16, Belvedere Road, Lambeth, S.E. 1, requires

Materials for Vacuum

BRAKE GEAR. Tenders due Two p.m. on 4th May, 1923. Tender Forms obtainable from above. A 235

METROPOLITAN WATER BOARD.

SUPPLY OF 24 INCH LAPWELDED STEEL TUBES—VINE STREET TO TOWER HILL SUBWAY.

The Metropolitan Water Board invite

Tenders for the Supply of

approximately 1400 feet of 24 inch LAPWELDED STEEL TUBES and SPECIALS. The place of delivery is New River Head, Clerkenwell, E.C., or other convenient site, the time for delivery being a period of eight weeks from the Engineer's order to commence work. The making of the field joints to be done in situ.

Forms of Tender, Conditions of Contract, etc., may be obtained on personal application at the Offices of the Board (Room 186), New River Head, 173, Rosebery Avenue, E.C. 1; or will be forwarded on receipt of a stamped addressed brief envelope.

Tenders enclosed in sealed envelopes, addressed to "The Clerk of the Board, Metropolitan Water Board, 173, Rosebery Avenue, E.C. 1," and endorsed "Tender for Steel Tubes," must be delivered at the Offices of the Board not later than Eleven a.m. on 4th May, 1923. The Board do not bind themselves to accept the lowest or any Tender.

G. F. STRINGER,
Clerk of the Board.
New River Head,
173, Rosebery Avenue, E.C. 1.
17th April, 1923. A 279

CITY OF LEICESTER.

NORTH BRIDGE WIDENING.

The Highways and Sewerage Committee of the Corporation of Leicestershire prepared to receive

Tenders for the Widening of

the NORTH BRIDGE over the River Soar, between Freg Island and Woodgate; comprising the Extension of the Masonry Piers, Abutments and Foundations, with Cofferdams; and for the SUPPLY and ERECTION of STEEL PLATE GIRDERS, STEEL TROUGHING, and for other works in connection therewith.

Drawings and General Conditions may be seen and Copies of Specification and Bills of Quantities obtained at the City Surveyor's Office on and after Monday, April 23rd, 1923, on payment of the sum of £2 which will be returned on receipt of a *bona fide* Tender. Cheques, etc., to be made payable to the Leicester Corporation.

Sealed Tenders on the Form supplied, addressed to the Chairman of the Highways and Sewage Committee, Town Hall, Leicester, are to be delivered not later than Twelve noon on Wednesday, 9th May, 1923, endorsed "Tender for North Bridge Widening."

The Committee do not bind themselves to accept the lowest or any Tender.

E. GEORGE MAWBEY, M.Inst.C.E.,
City Engineer and Surveyor.
Town Hall,
Leicester.
16th April, 1923. A 256

ADMINISTRATIVE COUNTY OF LONDON.

ABBEY MILLS PUMPING STATION ENLARGEMENT, 1923.

The London County Council invites

Tenders for the Construction

of FOUNDATIONS for a NEW INSTALLATION of ENGINES and PUMPS, BOILER FOUNDATIONS and ECONOMISER HOUSE, and the CONSTRUCTION of a NEW PUMPING MAIN between the Engine House and the Northern Outfall Sewers, and other works in connection therewith, at the Council's Abbey Mills Pumping Station, in the Borough of West Ham in the County of Essex.

Persons desiring to Tender may obtain the Form of Tender, etc., on application to the Chief Engineer at The Old County Hall, Spring Gardens, S.W. 1., upon payment of the sum of £5. This amount will be returnable only if the tenderer shall have sent in a *bona fide* Tender and shall not have withdrawn the same. Full particulars of the work may be obtained on personal application, and the contract document may be inspected before the payment of the fee.

No Tender received by the Clerk of the Council at the County Hall, Westminster Bridge, S.W. 1 after Twelve noon on Tuesday, 15th May, 1923 will be considered.

The Council does not bind itself to accept the lowest or any Tender.

JAMES BIRD,
Clerk of the London County Council.
A 274

THE SOUTH INDIAN RAILWAY COMPANY, LIMITED,
are prepared to receive

Tenders for the Supply of—

1. MISCELLANEOUS ARTICLES.
2. PLAIN LIGHTS.
3. FOUNDRY COKE.
4. LEATHER BELTING, etc.

Specifications and Forms of Tender will be available at the Company's Offices, 91, Petty France, Westminster, S.W. 1.

Tenders addressed to the Chairman and Directors of the South Indian Railway Company, Limited, marked: "Tenders for Miscellaneous Articles," or as the case may be, must be left with the undersigned not later than 12 noon on Friday the 4th of May, 1923.

The Directors do not bind themselves to accept the lowest or any Tender.

A charge, which will not be returned, will be made of 2/6 for each copy of Specifications No. 1 and 2, and of 10/- for each copy of Specification No. 3.

Copies of the Drawings may be obtained at the offices of Messrs. Robert White and Partners, Consulting Engineers to the Company, 3, Victoria Street, Westminster, S.W. 1.

A. MUIRHEAD,
Managing Director.
91, Petty France, S.W. 1.
17th April, 1923. A 275

G. R.

SALE OF PUMPING MACHINERY AND PLANT.

Sealed Tenders will be

received by the DIRECTOR OF ARMY CONTRACTS until Eleven a.m. on the 7th May, 1923, for the PURCHASE of the following MACHINERY and PLANT with accessories, lying at the Royal Arsenal, Woolwich:—

Three Horizontal Hydraulic Pumping Engines.
Two Vertical Pumping Engines.
Two Centrifugal Pumps.
Two Lathes.
Surface Condensing Plant.

Forms of Tender, Conditions of Contract, and any further particulars, may be obtained on application to the DIRECTOR OF ARMY CONTRACTS, (D.C. 7), Imperial House, Tothill Street, Westminster, S.W. 1. A 271

APPOINTMENTS OPEN.

UNIVERSITY OF LONDON.

The Senate invite

Applications for the Ramsay

Memorial CHAIR of CHEMICAL ENGINEERING tenable at University College.—Full particulars may be obtained from the ACADEMIC REGISTRAR, University of London, South Kensington, London, S.W. 7. X173

Architectural and Engineering

ASSISTANTS.—SENIOR and JUNIOR ASSISTANTS REQUIRED.—Applicants should have served with H.M. Forces, and should forward by letter full particulars of professional training and experience, service qualifications, age, and salary required, to

THE SECRETARY (S.I.),
AIR MINISTRY,
Kingsway,
London, W.C. 2. A 269

MINISTRY OF TRANSPORT.

Applications are Invited

for TWO APPOINTMENTS as ASSISTANT ENGINEERS in the Roads Department of the Ministry of Transport on the scale £200–20–500 plus bonus. Assistant Engineers are eligible for promotion to the class of Engineering Inspectors on the scale £600–25–800 plus bonus.

Successful Candidates will be appointed at commencing salaries of £200. The current Civil Service Bonus will be paid in addition, giving at present a commencing salary of £313 4s. 0d. per annum. The Bonus is subject to revision according to the cost of living index figure.

The appointments will be permanent and pensionable, and selected candidates will be required to serve a two years' probationary period.

Candidates should be Corporate Members of the Institution of Civil Engineers or should hold some equivalent professional qualification. Experience of Road and Bridge Construction is essential and actual municipal experience is an advantage. Candidates should be not more than 35 years of age, and should have served in His Majesty's Forces.

Forms of application can be obtained from the ESTABLISHMENT OFFICER, Ministry of Transport, 6, Whitehall Gardens, S.W. 1. Applications can only be received on the recognised forms and should reach the Ministry of Transport on or before the 30th April. A 189

Applications are Invited by

Manchester Engineering Firm for the POSITION of DRAUGHTSMAN with good General Engineering knowledge and experience, and familiar with Steam Plant, Pipework lay-out, and details. Age 24/40. Electrical experience an advantage. State age, experience and salary required.—Address, A 258, Offices of Engineering.

Wanted, an Experienced

ENGINEER as Assistant to the Chief of a large Testing Department, for the responsible testing at makers' works of steam turbines driving alternators and continuous current dynamos from 300 to 6000 HP.—Address, stating age, experience, and salary required, A 210, Offices of Engineering.

Wanted, First-class Draughtsman,

thoroughly conversant with MACHINE CUT GEARING and ITS APPLICATION. Apply, stating age, full experience and salary required. Only competent men need apply. —DAVID BROWN & SONS (Huddfd.) Ltd., Park Gear Works, Lockwood, Huddersfield. A 262

Draughtsman Required, ex-

perienced in Rotary Printing Press work.—Write full particulars, R. HOE & CO., Ltd., 196, Borough Road, London. A 264

Dust Removal.—Westminster

Engineering Firm REQUIRES LEADING DRAUGHTSMAN with extensive theoretical and practical knowledge of Ventilating, Heating and Dust Removal plants. Must be able to design and estimate complete installations. State fully training, experience, age, salary required, etc.—Address, A 227, Offices of Engineering.

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Wanted, by Well-known

Internal Combustion Engine Manufacturers, COMPETENT and EXPERIENCED DESIGNER of High Compression Solid Injection Cold Starting Heavy Oil Engine. Only applicants with the highest qualifications should apply.—Address, giving full particulars of career to date and state approximate salary required, A 179, Offices of Engineering.

Draughtsman Wanted,

thoroughly experienced in the design of Colliery Electric Winding Engines and Haulage Gears (mechanical portions).—Write, stating age, experience and salary required, BOX 1278, Bell's Advertising Offices, Fleet St., E.C. 4. A 204

THE MEASUREMENT OF AIR FLOW.

The Measurement of Air Flow by means of a Throttle Plate with Special Reference to the Measurement of the Air Supply to Internal Combustion Engines.

By R. O. KING, M.A.Sc.(McGill).*

(*Concluded from page* 458).

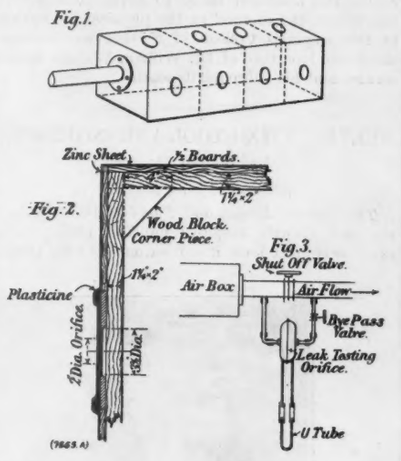
(8) *Selection of Orifice Sizes.*—In order to obtain maximum accuracy an orifice should be selected such that the air flow to be measured will when passing through it give a difference of pressure that is accurately readable. For instance, if the air supply to a 40-h.p. engine were to be measured it would be expected that the quantity required would be about 40 grammes per second.

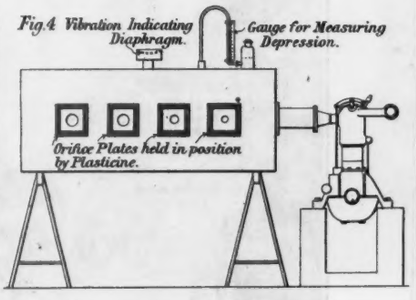
Referring to Table I, page 457 *ante*, the discharge rate for a 2⅛ in. orifice is 33·40 grammes per second for 1 in. difference of pressure, so for 2 in. it would be $33{\cdot}4 \times \sqrt{2} = 47{\cdot}1$ grammes per second, and this 2⅛-in. orifice would be a very suitable size to use. It will be noted that data are not given for larger sizes. If approximate measurements to an accuracy of 2 per cent. only are wanted, orifice sizes up to 6 in. diameter may be used, the discharge rate for these being based on Table I and taken as proportional to areas. Similarly the difference of pressure might be run up to as much as 6 in. of water and the discharge rate taken as proportional to the square root of the pressure. For example, the discharge rate from Table I for a 2-in. orifice under 1 in. of water difference of pressure is 29·62 grammes per second, and from this, — discharge rate for 6-in. orifice under 6 in. of water pressure $= 29{\cdot}62 \times \frac{62}{22} \times \sqrt{6} = 653$ grammes per second, and this single orifice would measure the air required by a 600-h.p. engine. If air flow greater than the discharge rate given for the largest size orifice in Table I is to be measured accurately, two or more orifices can be used in parallel. In using two orifices in this way it is necessary that their distance apart from centre to centre should not be less than 2½ times their diameter. Aside from this consideration the position of the orifices in an air box is of no importance, except that it is not advisable to place an orifice directly opposite an air exit. The most convenient arrangement is to draw air from the end of the box and arrange openings for the insertion of orifices in the sides.

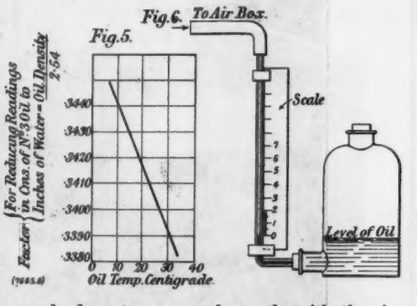
(9) *Making of Orifice Plates.*—The orifices used in obtaining the data given in Table I were cut in tin plate of No. 27 S.W.G. or 0·4 mm. thickness. In making new orifices it is desirable to use this thickness. The orifices should be bored in a lathe in the centre of 6 in. squares of tin plate. It is important that the edges of the orifices should be square. A simple way of ensuring this is to clamp the tin plate firmly between two pieces of ½-in. thick flat brass plate on the face plate of a lathe, and then bore straight through the brass and tin plate. Three or four orifices can be made in one boring operation in this way, and a set of orifices from the smallest to the largest size can be made by the use of one pair of brass plates if the smallest size is bored first. Care should be taken to have the brass plates quite flat and to make certain of this they should be faced in the lathe. After the orifices are bored in the plates any burr left on the edges should be removed; this can be done without appreciably rounding the edges. A very slight dulling of the sharp edge such as might occur in the making as described, does not affect the accuracy of measurement to one-fifth of 1 per cent.

That orifices can be easily made sufficiently near exact duplicates of standard orifices for which rates of discharge have been very accurately obtained, is one of the greatest advantages of the throttle-plate method of measuring air flow. The extreme error due to rounding completely an orifice has been determined by Dr. Watson. It varies in amount from 1·7 per cent. for 2-in. orifices to about 5 per cent. for ½-in. orifices.

It is preferable to bore the orifices to standard sizes to fit plug gauges. When finished the orifices should be measured accurately on two diameters and the size stamped in the metal. This, of course, is of most importance when plug gauges are not available. The diameters can be conveniently measured with a sufficient degree of accuracy by a vernier caliper reading to thousandths of an inch. It is not essential, but only a matter of convenience that the orifice sizes should be the same as given in Table I. The air flow per second per 1 in. difference of pressure can be readily obtained for any intermediate size by interpolation, taking the flow to vary as the area of the orifice. In any case a correction based on this method should be applied if measurements show that the sizes of the orifices as made do not correspond exactly with the sizes given in Table I. This correction is important because an error in diameter is doubled for corresponding air flow due to air flow being proportional to the square of the diameter for equal differences of pressure.







(10) *Construction of Air Boxes and Arrangement of Orifices.*—An air box to be convenient for use must be light and strong, and it is essential that it should be air tight. Although in ordinary use the pressure on the box will not greatly exceed 2 in. of water it is desirable that the box should be strong enough to stand up to 12 in. of water external pressure in order to provide for considerable accidental pressures and for freedom from distortion leaks. It has been found that a covering of ½ in. boards over a light but strong framing makes a sufficiently strong box. The entire outside should be covered by sheet zinc with the joints carefully soldered. This construction is shown in Figs. 1 and 2. It is important that the framing members be as light as possible and so placed as to offer no interference to the free flow of air from the orifices. Similarly, in cutting orifice holes in a box already constructed regard should be had to the position of the inside frame members. Fig. 1 shows a convenient size of air box; it is 5 ft. long and 2 ft. square; there are three inside frames in addition to the end frames. This allows for the placing in favourable positions of 12 orifices, The holes cut through the zinc and wood casing for the orifices should be at least 1½ in. larger in diameter than the largest diameter orifice to be used and chamfered off on the inside. The number of orifice openings in a box should only be sufficient to give the selection of orifices required for the air measuring work to be undertaken. An unnecessary number only increases liability to leakage. When working with a restricted number of orifices making necessary occasional changing of orifice sizes, a convenient and very satisfactory procedure is to stick orifice plates to the sides of the box by plasticine. This material will also be found very satisfactory for stopping air leaks, and a supply of it will be found very useful. It can usually be obtained from stationers, toy dealers or artist's supply shops. Orifices when not in use should be closed by soft rubber stoppers. Cork stoppers should not be used, they are very likely to leak air and to damage the edges of the orifices.

An air box made up as described is shown on Fig. 4, and set up for measuring the air taken by a Beardmore engine when motored round cold. This box is used for miscellaneous experimental work. It will be noted that the orifice plates are secured in place by the use of plasticine.

(11) *Measurement of Pressure Difference.*—The pressure difference over the orifice to be measured is in effect the depression in the air box below atmospheric pressure. It must be obtained in inches of water in order to apply the data given in Table I. The ordinary U-tube form of manometer (Fig. 3) is generally used for measuring pressure differences in inches of water. It is found, however, that water is a very unsuitable liquid to use for measuring such small differences of pressures as from 1 in. to 2 in. The meniscus at the top of the water column is usually distorted by the sticking of the water to the glass, and for the same reason the observed difference in height of the two columns is not always that due to the difference in pressure. Water, however, is the most convenient liquid to use, but on a difference in height of only up to 2 in. the accuracy of measurement will not generally exceed 1 per cent. to 2 per cent. A much more suitable liquid is oil, but it should be transparent and of very low viscosity and vapour pressure. The refined paraffin oils used for medicinal and cosmetic purposes are most suitable. They are supplied in quantity by the Anglo-American Oil Company in three grades. What is known as No. 3 white oil should be used when it is desired to have the gauge respond quickly to changes of pressure, its viscosity being very low. With oil as a gauge liquid a fine bore tube (2 mm. to 4 mm. diameter) should be used, as this gives a sharply-defined meniscus, and readings can be made to one-tenth of a millimetre. Allowing for the density of the oil 60 mm. will correspond to about 2 in. of water, and reading to one-tenth of a millimetre means that the difference of pressure over the orifice can be obtained with an accuracy of 1 part in 600 for this case.

Differences of pressure observed in millimetres of oil require to be reduced to inches of water, and allowance must be made for the very considerable variation of the density of oil with change of temperature. It is convenient to make this reduction in one operation, thus—Pressure difference in inches of water:—

$$= \frac{\text{Oil gauge reading in cm.} \times \text{density}}{2{\cdot}54}$$

$$= \text{Oil gauge reading in cm.} \times \text{reduction factor.}$$

The reduction factor will depend on the oil density at the temperature at which it is used. Fig. 5, gives reduction factors over the usual range of temperature for No. 3 white oil.

A convenient form of oil gauge suggested by Professor Callendar is shown in Fig. 6. One of these is also shown in Fig. 4. This form of gauge avoids the inconvenience of reading two heights of

* Formerly Exhibition of 1851 Scholar and Whiting Fellow in Physics, Harvard University; in charge Engine Section, Air Ministry Laboratory, London.

liquid and subtracting to get difference of pressure. In the form shown in Fig. 6, a scale is clamped to the vertical tube, and the height through which the liquid is observed to rise is taken as giving a measure of the depression in the air box. Actually the height through which the level of the liquid in the bottle falls should be added, but by making the tube of say, 2 mm. to 4 mm. bore and using a bottle of 3 in. or 4 in. diameter, the correction for the change of level in the bottle is quite negligible.

(12) *Tests for Leaks.*—It is of the very greatest importance in air flow measurement that air leaks should be prevented. The prevention of leaks is perhaps the most difficult part of the experimental work. An air box should be carefully tested for leaks before being used particularly when small air flows are to be measured. There is no better way of emphasising the extreme importance of this part of the work than by quoting the observations made by Dr. Watson and Mr. Schofield as follows:—

"The air boxes were made as nearly airtight as possible, and then pumped up to some definite pressure as registered on a manometer attached to each box. The time was then taken for the pressure to fall to half its initial value. From this the leak per second could be calculated since the cubical capacity of the box was known. The places where the leak occurred were located by filling the boxes with coal gas and finding the points at which the issuing gas could be ignited. These were stopped by Chatterton cement and the rate of leak determined again. In this way the process was repeated until any leak obtained was so small that it could not affect the percentage of accuracy aimed at in the experiments. The whole of the apparatus was treated in this way, using higher pressures than it had to stand during the actual tests.

"The stoppage of leaks in all parts of the apparatus proved to be a most difficult task, and it was only after considerable time had been spent that this was finally accomplished. The boxes now used for the application of this method to engines are made of wood covered outside with zinc, all joints being soldered, so that once the leaks are stopped no further difficulty arises."

Referring to the last sentence of this paragraph it has been found that soldering is not a permanent remedy for leaks, and even after the greatest care has been taken in making airtight soldered joints, periodical testing is required to ensure that they have remained so.

An ingenious method of testing for air leaks and of actually measuring them was suggested by Professor Callendar, and has been very successfully used in practice. This method is to draw the leak air through a very small measuring orifice. A difference of pressure over this orifice indicates a leak and at the same time measures it. At the end of Table I, the discharge rate for an $\frac{1}{4}$-in. orifice is given. If it were found that the leak air were sufficient to give, say, 4 in. of water difference of pressure over this orifice then the amount of the leak would be $0{\cdot}12\sqrt{4} = 0{\cdot}24$ grammes per second, that is 1 per cent. on 25 grammes per second, the supply required by a 25-h.p. engine. A leak passing this amount of air is often found in apparatus that is apparently quite airtight. A convenient arrangement of this leak measurement method is shown in Fig. 3. The leak orifice is placed in a bye-pass around a shut-off valve in the pipe through which the air flow from the box takes place. At any time during an experiment the main valve can be closed. The measuring orifices are stopped the bye-pass valve opened anc after the depression in the air box has reached a steady state, the difference of pressure over the leak orifice will give a measure of any leak in the box or connections up to the main valve.

In some particular cases of air measurement, such, for instance, as measuring the air supply to an engine running under its own power, it is desirable to keep the length of connection between the air box and the induction pipe as short as possible, and the introduction of a shut-off valve and bye-pass would not be advisable. Besides the engine would not run on the leak air, and the method could only be used if means, such as are provided by an electric dynamometer test bed, were at hand for motoring the engine round slowly. For such cases, it is recommended that the leak testing orifice be used by attaching it directly to the air box and drawing air out of the box, and through it, by the use of a small centrifugal fan, first cutting off the main air outlet from the box by "blanking off" a flange connection. It is much better to take a little trouble in testing and measuring leaks in this way, than to find after a long series of experiments that the results are quite unreliable due to unsuspected leaks.

In preparing this article advantage has been taken of suggestions made by Professor H. L. Callendar, and by Dr. Herbert Moss and Mr. W. J. Stern, the intention being to cover generally the practice of the method in the physical laboratories of the Imperial College of Science as developed since the departure of Dr. William Watson for war service and his subsequent death.

MULTI-CUTTING TOOL ARRANGEMENTS.

By JOSEPH HORNER.

(*Continued from page* 421.)

The Vertical Boring and Turning Mill.—This, in its later growth, employs multiple tools. In its original simpler form it carries one tool for turning or boring in a holder on the cross rail. Or two holders may be carried thus, and one on a housing. The last development, which is growing, is that of a turret on the cross-rail, supplemented with one at one side. This is in effect the turret lathe, with its axis set vertically, just as the simple vertical boring and turning machine resembles the horizontal lathe with its axis similarly changed.

An aspect of work done on these machines is, that the cutting is accomplished with single-edged tools. Cuts can, therefore, be deep, and feeds coarse without setting up excessive strains in the work, with distortions. When milling cutters are used, speeds and depths of cut per tooth must be lessened. As in turret work, the time of the longest cut is taken as the basis, and the others, even though not done at the most economical speed, are so of time, since they are all accomplished within the period occupied by the longest. Also, as in ordinary turret work, either a simple tool, or tool holder can be mounted on a face, or as frequently something more elaborated—a holder carrying more than one cutter. Boring bars, and reamers are also freely employed. With these combinations, there is a very wide field for tooling articles that have to be turned, bored and faced. The vertical turning and boring mill, equipped with a turret or turrets, therefore, fulfils similar functions for a heavy class of work that the common turret lathe does for the lighter, and smaller articles. In many cases, two distinct tables, each with its turret are fitted. The additional tool-holder mounted at one side greatly increases the range of utility of the machine, as by its aid external tapers are turned, and curved profiles, and the crowning of pulleys. Parting off is done. Its functions, therefore, broadly correspond with those of the cross slide of a common turret lathe. Usually the work is held directly in a common jaw chuck, with the advantage which the design gives of a horizontal setting, which is appreciated in the case of heavy pieces, and when several pieces are arranged in a circular series. Fixtures for repetitive work can be held in the chuck, which is either of the independent jaw type, or of the combination design.

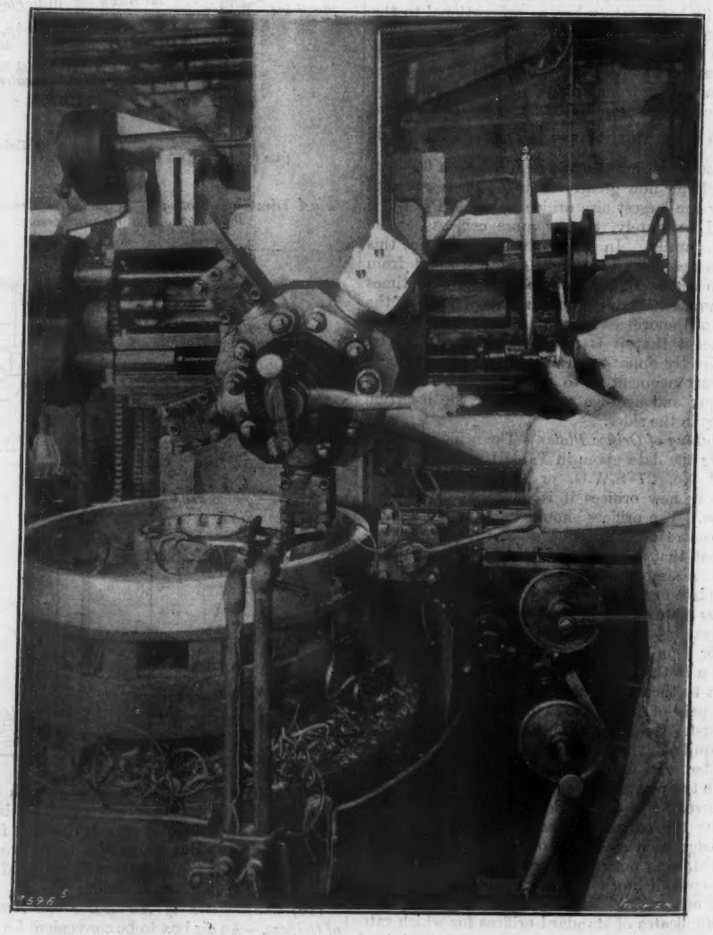


FIG. 110. BULLARD VERTICAL BORING AND TURNING MILL.

Work done on the Bullard Machine.—In this machine (The Bullard Machine Tool Company,

MULTI-CUTTING TOOL ARRANGEMENTS.

Fig. 111. Battery of Bullard Machines at the Works of the Dayton Steel Foundry Company.

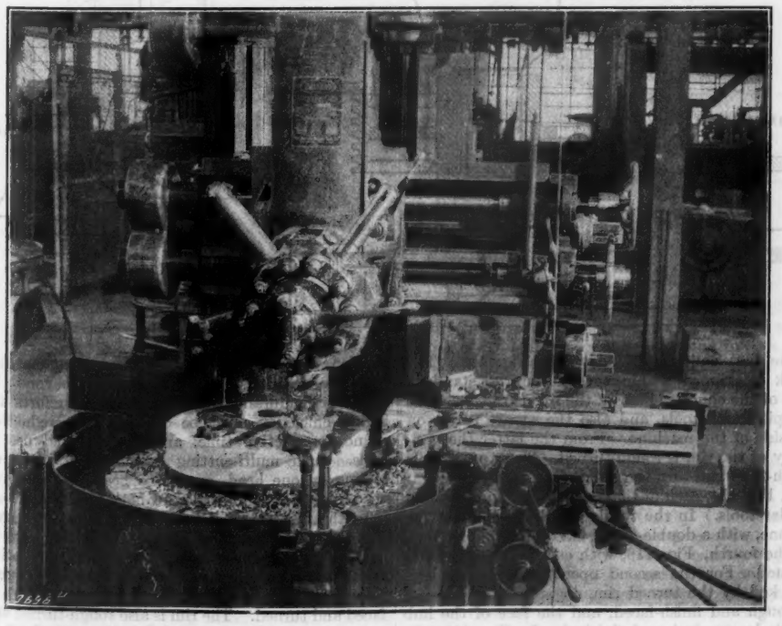


Fig. 112. Machining a Split Gear Blank.

Bridgeport, Conn., U.S.A.) the main turret slides with a narrow guide on the cross-rail, and has five flat faces with holes to receive any of the ordinary single tools, or box tools. The saddle of the side turret moves vertically on a slide, and is carried at the end of a horizontal arm moving in a slide, with graduations. The weight of each is counterbalanced. The drives are all derived from a single belt, running over a pulley at constant speed, driven from shaft, or motor, and powerful enough for the heaviest cuts. Provisions of scales, micrometer dials, and adjustable observation stops permit of the ready setting of tools, and of dimensions. All levers and handles are accessible from one position.

Combination features.—In the development of machine tools for effecting increased production with lessening of cost, the principle has been sometimes adopted of combining the salient features of two or more types of machines into a single unit to include the advantages afforded by each type, and thus produce a machine of wider range, increased adaptability, and more economical operation. Materials are improved, centralised control is embodied, and production is increased. The Bullard lathe combines the advantages of the common lathe, the horizontal turret lathe, and the vertical boring and turning mill. Based on the fact that all time is either being used, or not occupied in production, and that actual cutting time alone is productive, the problem with any machine is first to reduce the non-productive time, with a corresponding increase in the productive, and, second, to intensify the employment of the time in actual operation. The

reduction of time between cuts is effected by the convenience of the control exercised, by the elimination of unnecessary movements, and affording direct aid to those that are necessary. The use of productive time is intensified by the number of cuts which can be taken at once with proper feeds and speeds, the limiting factor in each cut being the ability of the cutting tool to endure under these conditions.

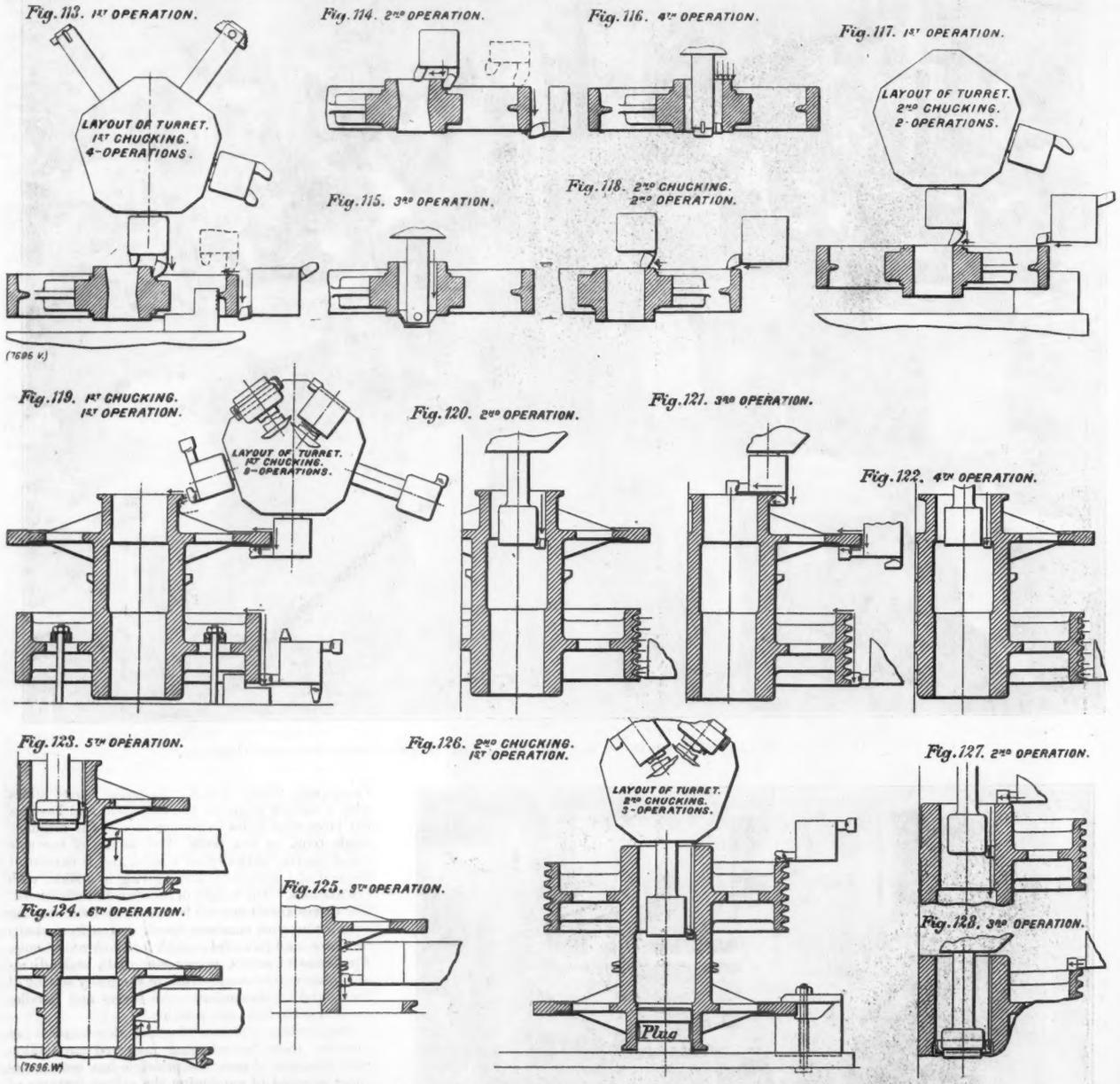
The vertical turret lathe of modern design illustrates the application of these developments. The performance of a battery of Bullard machines at the works of the Dayton Steel Foundry Company, Figs. 110, 111, affords a good example of their capacities for dealing with heavy work. It also emphasises efficiencies of cutting. Thus, each machine was installed for a production of 18 truck wheels per day, in cast manganese steel. The operations were rough turning, boring, facing, and finishing. With tool steel a speed of 40 ft. per minute was used for roughing, and 65 ft. per minute for finishing. By a change in cutting steel a roughing speed of 90 ft. per minute, and a finishing speed of 150 ft. per minute were obtained. Production was doubled to 36 wheels per day from the same machines. The second photograph, Fig. 111, illustrates two batteries of machines being engaged in this repetitive work.

A complete study of the successive operations in the machining of a split-gear blank of forged steel, 26 in. in diameter, affords an excellent opportunity of observing the efficiency of the machine under heavy duty, and shows the value of turret tooling and multi-cutting. A photograph of the work is illustrated in Fig. 112, and line drawings of the piece, and the lay-out of tools are given in Figs. 113 to 118. The successive operations are stated in the Table appended, showing clock times, speed, feed, and duration of each operation.

The first chucking is shown in Fig. 113. The blank is gripped within the rim in the standard jaws of the chuck. Four of the five turret faces are occupied with tools, and also the square turret on the side of the machine. From the latter the periphery of the rim is rough-turned. Two turret tools rough-face, and turn the hub. In the second operation, Fig. 114, each of these surfaces is finished with similar tools. In the third, Fig. 115, rough boring is done, with a double-ended flat cutter, and finished in the fourth, Fig. 116, with cutters in a bar, and reamed. For the second operations the blank is chucked by the turned rim, Fig. 117, and the rim is rough and finish-faced, and the face of the hub similarly roughed and finished. In Fig. 118, the hub and rim are finished. The reparate times are given on the Table.

The machining of an elevator drive sheave, Figs. 119 to 128, demonstrates the advantages of turret tooling in both the main and side heads. The actual time for tooling complete is slightly over four hours. The piece was previously done on a common lathe in 36 hours. An analysis of the operations in machining will indicate that, with speeds and feeds corresponding with the capacity of the tools and the requirements of the work, the total cutting time per tool for any piece will be the same. On any machine therefore, which is capable of working beyond the economic endurance of cutting metal, efforts for higher efficiency must be directed to a reduction of non-productive time, and a multiplied use of tools. Such multi-cutting is the result of group tooling on one head, or of two heads operating at one time, or a combination of both methods.

In the first stage of tooling the elevator sheave, Fig. 119, the chucking is done with the jaws in contact with the interior of the rim, and the casting is bolted down through the arms. The disc is rough-faced on both faces, and turned, and the hub is faced and turned. The rim is also rough-turned and faced on one side. Afterwards, Fig. 120, the boss



is rough-bored with a single-ended tool, and the grooves are roughed out with a tool having serrated edges. Then, Fig. 121, the edges, and periphery of the disc are finished, and the face and edge of the hub finished, the pulley grooves turned with a smooth edged cutter, and the periphery of the rim finished. In Fig. 122 the grooves are finish-turned. In Figs. 123 to 125 the body between the rim and the disc is being rough and finish-turned. For the second operation, the piece is rechucked, Fig. 126, by the disc already turned, secured in four special blocks with clamp plates and bolts, and located centrally with a plug fitting that portion of the hole previously bored. The top edge of the rim is rough-

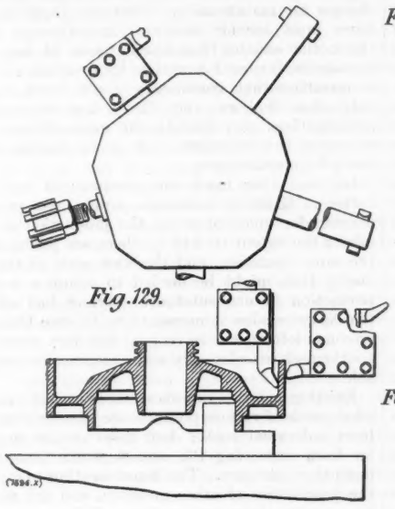


Fig. 129.

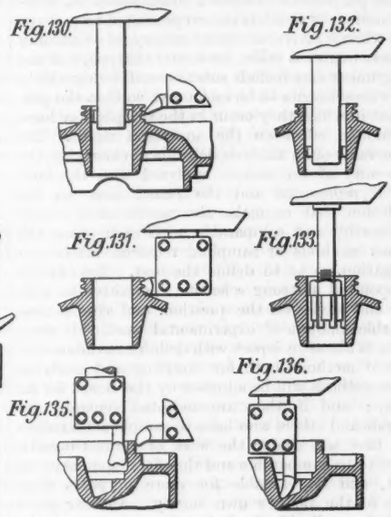


Fig. 130.

Fig. 131.

Fig. 132.

Fig. 133.

Fig. 135.

Fig. 136.

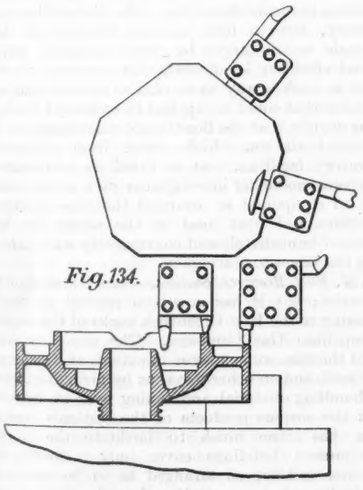


Fig. 134.

turned, and the upper portion of the hole rough-bored, to be completed as in Figs. 127, 128.

Another example of tooling is shown by Figs. 129 to 136. The clutch pulley is chucked by the internal portion of the rim, using the common jaws, Figs. 129, and that portion of the rim which faces outwards, is bored and turned. In Fig. 130 the outside of the hub is turned. In Fig. 131 the grooves are cut, in Figs. 132, 133, the hub is bored and reamed. The piece is now rechucked (Fig. 134) with outside jaws, and the various top faces are dealt with, followed by the turning operations in Figs. 135, 136.

The varied character of the tool equipment is well illustrated by these drawings. Among other examples is that of a flywheel, being turned on the rim, faced and bored simultaneously, the boring being done with two tools working on separate diameters. The turning is performed with one tool on the square turret at the side, which carries a roughing, a finishing tool, and a scrape. The spring rings for pistons are turned from a deep ring. After turning, a parting tool is held in the side head, cutting in horizontally to a certain depth, after which a tool fed from the main turret takes a cut through the interior, and meeting the cuts from the outside severs the rings in succession; a method which avoids fins. External tapers of low-angle are turned with a tool on the side head, fed vertically, while the turret slide is forced outwards by means of a tapered form block set in one of the main turret holders, against which a roll in the side turret makes contact. Bevel gear blanks have their bevelled faces turned with a tool made to the same angle, and held in the side turret. At the same time a flat-ended tool in the main turret turns the adjacent edge. Flanged pulleys are faced on rim and boss, while the exterior is crowned. For the latter, the side head is coerced by means of a forming attachment—a slotted head within which a roll is moved, secured to the tool slide. Differences in the curvature of the crowning require different plates. For ordinary bevels, a guide slot is set to the angle required—an index moving over a scale of degrees provides for precise setting.

SPLIT GEAR BLANK—FORGED STEEL.

Operation.	Clock Time.	Speed.	Feed.	Main Head.	Side Head.
		r.p.m.		min.	m.
1st chucking... ...	2·14 2·17	—	—	3	—
Rough turn O.S.diam.	2·17 2·29	13	0·033	—	12
Rough face rim ...	2·19 2·21½	13	0·033	2½	—
,, ,, hub ...	2·21½ 2·25	13	0·033	3½	—
,, turn ...	2·25 2·28½	13	0·033	3½	—
Finish turn O.S.diam.	2·29 2·30½	13	0·245	—	1½
Finish face rim ...	2·29½ 2·29½	13	0·245	½	—
,, ,, hub ...	2·29½ 2·30½	13	0·245	½	—
Rough bore (spec. bar)	2·30½ 2·35½	56	0·018	5	—
Rough bore multi bar	2·35½ 2·39	56	0·033	3½	—
True multi bar ...	2·39 2·41½	56	0·066	2½	—
Size ,, ,, ...	2·41½ 2·43	19	0·131	1½	—
Ream ,, ,, ...	2·43 2·44½	19	0·131	1½	—
Take off	2·44½ 2·46½	—	—	2	—
1st chucking, total time	32½ min.	—	—	—	—
2nd chucking ...	9·51 9·52½	—	—	1½	—
Rough face rim ...	9·52½ 9·55	13	0·068	2½	—
Finish face rim ...	9·55 9·56	13	0·068	—	1
Rough face and turn hub	9·56 9·58½	39	0·033	2½	—
Finish face hub ...	9·58½ 9·59½	56	0·033	1	—
Take off	9·59½ 10·01	—	—	1½	—
2nd chucking, total time	10 min.				

(To be continued.)

THE FUEL RESEARCH BOARD.

I. ITS ORIGIN AND OBJECTS.

Introductory.—The Privy Council Committee for Scientific and Industrial Research was formed by Order in Council in July, 1915, to direct the application of Parliamentary votes for organising and developing scientific and industrial research, and an Advisory Council was instituted on whose report or initiative the committee might act. The council started with three Standing Committees of its own, dealing respectively with Engineering, Mining, and Metallurgy; and though from the outset the scope contemplated for the department was in no way restricted to the engineering trades, but included the whole of industry and of the sciences by which it is fertilised, the importance of the Research Department to the interests of the engineering trades has in no way decreased with the extensions of its purview, for most of the industries whose development is concerned in these extensions are among the best customers of manufacturing engineers.

When in 1916 the Reconstruction Committee appointed a Sub-Committee on Coal Conservation, one of that sub-committee's first acts was to approach the Advisory Council of the Research Department with the object of securing its co-operation, and in particular of obtaining the institution of a survey of British coalfields, which should collect not only analyses of the various deposits on a uniform and readily comparable basis, but also data on the behaviour of the coals under furnace tests and on their suitability for various purposes, such as coking, metallurgical use, and steam raising. The council had already received similar applications for help in one form or another from the British Association, various professional societies, and research workers at universities, and with the assistance of Sir Richard Redmayne, Chief Inspector of Mines under the Home Office, had prepared a memorandum on researches on coal and its uses in progress or proposed. As the result of a series of conferences between the several bodies interested it was agreed that the research work on fuel which needed to be undertaken was too great and important to be administered satisfactorily by the suggested mechanism of a fresh Standing Committee, reporting on each proposed step to the Advisory Council for submission to the Privy Council Committee. Accordingly the Fuel Research Board was constituted, with a director responsible directly to the president of the council, and having power to frame a budget for each year, which when approved by the committee on the council's report, would provide the year's funds for the service of the approved scheme of work, without further reference to the council or the committee in regard to the individual measures it might entail.

No doubt can be felt that the importance of conserving coal and of making its consumption more efficient, demands the most effective mechanism that can be provided. In round figures the coal consumed in this country is of the order of 200,000,000 tons a year, about half of which is spent on manufactures (including about a tenth in coke ovens), a tenth each in the coal mines themselves and in gas works, and a fifth in domestic uses. How much of this consumption is spent inefficiently is among the questions into which the Fuel Research Board has to inquire. Every one knows the amount of waste is large, and applied to these huge quantities any coefficient that expresses the possible saving to be effected must represent a colossal sum. On the other hand a body charged with the inquiry into such large questions, the solution of which involves necessarily and obviously a vast amount of experimental work, must itself be a considerable enterprise, and both by reason of its expenditure and the gravity of the questions that are entrusted to it, its proceedings and progress should be watched carefully by such interested parties as can appreciate them. This is particularly true of the work of a Government body. No one who knows the internal work of Government offices can doubt the average competence of Government officers, and the admirable zeal of many of the most highly-placed among them. In at least two ways, however, Government work is done under exceptional disadvantage. The need to express regulations in general terms must necessarily operate to limit the discretion of officers in many respects in which discretion would be used with advantage in private life, and for a Government officer the line of least resistance lies above all in unquestioning conformity with regulations. Few officers can take any other line successfully, and as a result compromises have to be adopted between regulations and efficient service, which would be neither needed not tolerated in private enterprise. A Government service, moreover, may not be wholly outside political influences. Its head is a member

of the Government, and a Government is not only itself the head of a political party or parties, but is accessible to the demands of other political parties whom it may be desirable to conciliate. Work entrusted to a Government department, even one in which officers are of unquestionable competence and reasonable aptitude for reconciling the demands of their service with those of efficient work, may accordingly be delayed or distorted by influences from on high. A circumstance, again, of Government departments is that sometimes they have both the opportunity and the disposition to magnify their office, and its efficiency may fall as its magnificence increases.

Pure Research and Practical Problems.—These general considerations commend the examination of Government work, and they may be applied to the work of the Fuel Research Board with the more satisfaction because up to now it seems to have kept itself on the whole free from their influence. Research work is particularly open to the criticism that those engaged on it pursue investigations of no practical use. The suggestion, though easy to make, is difficult to rebut, because while an investigation is in progress it is often hard or impossible to say whether in fact it will have any practical result. The safe way of avoiding such criticism is, of course, to confine investigations to those that have a directly practical purpose, and to exclude those of which the object is merely to extend the circle of knowledge and increase the material out of which subsequent investigators may—or may not—arrive at practical results. Doubtless such restrictions may save the skin of the prudent and sensitive investigator, but all the same they may be a betrayal of his trust. Some problems cannot be solved without more knowledge than is available, and not the least important duty of research is to extend the domain of pure knowledge. Such extensions can never be sought with any certainty that when they have been made they will be found to contain the solution of any problem whatever, and will be avoided by institutions whose interest is less in promoting their own work than in safeguarding their latter end. Yet the history of all discovery has shown that in the long run the most fundamental progress has turned out to have resulted from extensions of pure knowledge, and that an industry must suffer if the sciences on which it depends are not extended opportunely.

To judge how far its resources should be addressed to pure research and how far to the solution of practical problems and the scientific testing of proposed solutions, an institution for research must doubtless have not only scientific and technical competence, but also a rare discretion and sense of perspective. The Fuel Research Board—a body of three men, each distinguished both in science and in industry, and none of them Government officers—appears to be an eminently prudent and businesslike body, very desirous to know before it begins to prophesy, with as keen an eye as any private enterprise to the main chance of the interests it is serving. It has, indeed, given pure science a place in what a less competent and courageous body might have regarded as a purely practical scheme of investigation, and, as will be seen later, it has already been rewarded by new knowledge of practical importance. But for the most part it has up to now addressed its resources to the scientific solution or examination of purely practical problem.

Coal Survey and Methods of Treatment.—As explained above, the Board's inception was due primarily to the representations of bodies outside the Research Department, some within the Government and some independent of it, and the subject to which the Board's attention was invited was the conservation of the country's coal resources. Accordingly the programme first contemplated was on the one hand a survey and classification of the coal seams in the various mining districts by means of chemical and physical tests in the laboratory, and on the other hand, the investigation of the practical problems to be solved if fuels prepared from coal by carbonising and gasifying processes are to replace the burning of raw coal to any large extent. The latter branch of investigation was dictated as being necessary to finding simultaneously more and cheaper electrical energy, home supplies of fuel oil for the Navy and of motor spirit for the Transport and Air Services, and smokeless domestic fuel ; and having regard both to the importance and the complexity of the problems involved in this investigation it was thought desirable to postpone active operations on the survey until a better knowledge of the circumstances of carbonising and gasifying could give some guidance in selecting the tests to be applied to the coals surveyed, and prevent the inconvenient and relatively useless accumulation of "an undigested mass of samples and chemical analyses."

In the meantime some fundamental preparations for the survey were put in hand, which should also be of general advantage. In particular the Board faced the obvious difficulties involved in sampling and in securing uniformity of analytical methods. For the purposes of analysis a consignment of, maybe, hundreds of tons has to be represented by perhaps 3 lbs. when it arrives at the laboratory, of which only as many ounces is taken for actual analysis, and the consignment may include substances differing widely in the constituents to be estimated, so that the proportion in which they occur in the sample may have a profound effect on the analytical result. The whole value of an analysis depends obviously on the conformity of the sample analysed with the bulk that it represents, and the Board came to the conclusion that to make the results of a survey trustworthy and comparable with each other the various methods of sampling required careful investigation, so as to define the best. Accordingly it appointed a strong scientific committee to consider and advise on the question, and after a considerable amount of experimental work this committee is about to report with definite recommendations of methods both for sampling and analysis. These methods will be adopted by the Board for its survey; and if they are accepted generally by analysts and others who have to sample and analyse coal, they will enable the work of various investigators to be comparable and therefore cumulative in effect, and be valuable for more purposes than those of the Board's own survey. Another piece of work applicable both to the purposes of the survey and to more general use has been the elaboration by Dr. Thomas Gray and Mr. J. G. King, of a method of assaying coal by distillation on a laboratory scale, which exhibits directly the type of coke and the yields of coke, gas and oil that will be obtained on a works scale when the coal under test is carbonised at a low temperature (550 deg. to 600 deg. C.).

For the survey itself a start has been made in the formation of local committees. These are to consist of mine owners, managers and consumers associated with representatives of the Fuel Research Board, the Geological Survey, and outside scientific men, and for the first of these committees the Board has recognised the Lancashire and Cheshire Coal Research Association, a local body not in receipt of any Government subvention, as the representative body in charge of the work. For the purposes of the survey the local committee sends up samples and particulars of the deposits in its district to the Board, where they are charted and recorded systematically. At the same time the committee defines and investigates as far as it is able any special problems that the deposits present, such for instance as a tendency to spontaneous combustion or the most suitable method of carbonisation, and refers them to the Board for further investigation as required. In one well-known seam, for example, the fuller investigation that the co-operation of the Board and the committee made possible disclosed the quite unsuspected fact that the character of the coal along the seam varied widely. One part yielded a coal that fused readily and swelled considerably on carbonisation, the next part when carbonised was very hard and dry, and on a further stretch of the seam coal of the first type appeared again. Circumstances of this sort illustrate how closely interdependent are the results of the survey and those of the carbonising and gasifying investigation, through which the detection of the variations in the seam had become practically possible, and vindicate the Board's restraint in not proceeding with the survey until their investigations into carbonisation and gasification had gone far enough to provide the means of giving a practical meaning to the survey results.

Coal Production and Use.—The Board's task on coal was conditioned by two fundamental circumstances, each of which affected the situation in every important aspect. On the one hand the material on which users of coal have to work is widely variable, and must require a wide variety of treatment in order to get the best out of it. The importance of thus turning the coal supply to the best account does not arise merely or, as yet, even mainly from the fact that coal resources are limited and do not renew themselves, but still more from the fact that the prosperity of other industries depends essentially on the cheapness of their fuel. This was true enough before the war, and the cost of every waste of heat value has now to be multiplied by the increased cost of the coal itself, with an addition in the coal-products industries to cover increased wages, capital costs of new plant, and revenue charges for maintenance. Thus the Board's purposes must include whatever investigation may check the existing inordinate waste of heat by consumers, favoured doubtless by practices that in a manufacturing community could have arisen only when fuel was very cheap, and what other investigations may lead to the more efficient use of coal in the industries, such as gas-making, that use it for manufacture.

On the other hand, the products of coal are various. Existing industries supply the present demand for much of them, the production of one affects the extent to which others are produced in the same operation, and the vast scale of the industry that might be needed to assure a desired production of one substance—say, of fuel oil for the Navy—makes it necessary to be sure that the products left when the fuel oil has been extracted are themselves technically and economically marketable.

Existing practice can show more or less exactly what yields of various products are actually obtained from individual coals; but these results may be far from expressing the utmost yields that other methods might give. The Board has thus to explore the possibilities of other methods, and not merely to ascertain the rearrangements of the proportions of various products that will give the highest thermal efficiency, but to take account broadly of the economic circumstances by which practical commercial efficiency is affected. To carry out these duties in such a way as to obtain assured results, in a form that could be applied to industrial works, it was evident that the Board's operations must need a central station, which, apart from adequate laboratory facilities, was so fitted as to conduct the operations under investigation on a works scale with an equipment so arranged that the weights, quantities and heat used in the works can be measured immediately and conveniently with something like laboratory accuracy.

H.M. Fuel Research Station.—Such a station did not exist; but it has now been erected on land belonging to the East Greenwich works of the South Metropolitan Gas Company. The company has leased the site, some 4 acres in extent, at a peppercorn rent, and in other ways, as by giving facilities for handling material and taking over at market rates the surplus products of the station's operations, has done much to facilitate the work. The present buildings cover only a fourth of the site, and are so arranged as to be enlarged or duplicated conveniently if and when occasion arises. Their equipment includes ample and convenient siding accommodation from the railway, and narrow-gauge lines at low and high levels running through the works and connected by an elevator, the levels and machinery being such that the coal after being crushed and raised by the elevator passes by gravity through hoppers to the levels of the gas producers, steam boilers, briquetting plant, carbonising plant and other apparatus in which it is to be used. In addition to these provisions for receiving and distributing coal and for delivering products, the permanent installation includes also means for weighing coal to be carbonised or gasified, collecting, measuring and storing gaseous and liquid products, collecting, weighing and distributing coke or char produced, and supplying and measuring the fuel gas used in every operation, so that an exact weight balance can be obtained on every test. The fundamental fuel for the station's operations is water gas of 300 B.Th.U. to 310 B.Th.U. per cubic foot, from a producer of the Humphreys

and Glasgow type, delivered into one or other of two 20,000 cub. ft. gasholders, from which it passes under a steady pressure of about 3½ in. of water through separate meters supplying each piece of experimental apparatus, the constancy of supply in furnaces being maintained by diaphragms of standard sizes. The air for combustion is also delivered and measured directly under a positive pressure and control at the point of combustion, the risk of leakage of cold or unmeasured air inward being thus avoided. In this way regular and accurate thermal balance sheets for almost any type of operation or apparatus can be drawn up with ease. The scale of operations is intended to be the least that will fairly represent industrial conditions, so as to avoid expense of time, material and labour. Though the general lay-out of the station would allow larger quantities to be handled it is not contemplated that more than 20 tons to 30 tons of coal or coke per day will in fact be treated, and a great deal of the most useful work will be done on a considerably smaller scale. Very complete arrangements are provided for separating tar and volatile hydro-carbons, purifying, metering and storing the gas produced, and measuring and storing liquid products. The receiving, crushing, weighing, elevating and distributing systems are all within the main building and under glazed roofing, so that the experimental work can be carried on night and day in complete independence of the weather.

These, with steam and electric supplies, are the principal features of the permanent lay-out, applicable to whatever special apparatus may come under test. Two principal plants have been erected up to now for investigation with the help of this installation. They are concerned with carbonisation at high and low temperatures respectively, and further reference will be made to them in subsequent articles, as the results obtained from each of them seem to be of general and fundamental importance. Among the incidental investigations that other work has demanded is one on the manufacture of water gas, designed to settle whether it is thermally more efficient to use a thin fuel bed burnt with a short blow right out to carbonic acid, as in the Dellwik system, or a thick bed with a longer blow burnt to carbonic oxide. The results will be reported shortly, but it may now be said that they show a slightly greater thermal efficiency in the carbonic acid blow, of which advantage can be taken in designing new plant for a site where ground space is no object; but in existing plant or where ground space is a consideration the higher efficiency is obtained at the cost of reduced output.

The Therm Unit.—The Board's function in helping to assure the efficient use of fuel is seen in the introduction of the therm as the unit for sale of gas. The Board's advice on gas standards was asked by the Board of Trade and other departments and was given after some eighteen months' investigation, the final recommendations being made after prolonged discussion and with the unanimous concurrence of the gas companies and representatives of gas engineers and consumers. In effect the problem was this. The gas companies were carbonising some 20,000,000 tons of coal a year and selling as gas something under a fourth of the heat contained in the coal. Whether for lighting or other purposes the consumers had come to use the gas almost entirely by methods in which the desired effect was produced by heat, and the gas companies had been put under the obligation to supply gas of a certain calorific value, which limited them in the gases they could use and the methods they could adopt. On the other hand the methods by which the calorific value of their gas was controlled safeguarded that value only at certain predefined times and places, and left the normal or average calorific value practically uncontrolled. The companies were in fact restrained from improving the efficiency with which they used their coal if the resulting gas fell below the prescribed calorific value, while nevertheless the consumer had often to pay for heat in excess of what he received. Accordingly it was decided that for the future the gas companies should declare the calorific value of the gas they intended to supply and have the conformity of the gas with the declared value controlled by a continuous record instead of merely by intermittent observations at predetermined times and places, while the consumer should pay only for the heat he received and should be entitled to look to the gas company to adjust and, if necessary, replace without charge the burners on his premises, so that they could burn the delivered gas safely and efficiently. The gas companies were further to be free to change the declared value of their gas on giving due notice, and arranging at their own expense for any necessary readjustment of their customers' burners. The reduction of calorific value entails necessarily an increased demand on gasholders and mains for a given thermal supply, and both for this reason and because of the expense of readjusting burners, companies would therefore not change unless a substantial economy was made in the utilisation of coal. As a fact many companies have made no change, and there is no great evidence that the consumption of gas has been affected by the change beyond the normal increase. The London County Council schools, for instance, have found no increase in their consumption. The latitude that the change gives the companies should certainly do something to increase the efficiency with which they use their coal, and if they really attend to the due adjustment of burners—a duty that perhaps consumers have not been able to enforce as fully as was contemplated in the Board's recommendations—the consumer will certainly be paying no more for his service than he would have paid under equivalent rates per 1,000 cub. ft. What complaint has arisen seems to have been due to a certain lack of candour on the part of the Board of Trade or the companies in not advising the public sufficently that with the change in method the companies were receiving an advance in the price of their gas, which, though it may have been just and even overdue, might have been paid more cheerfully if it had been more frankly admitted.

Other Work.—The Board has other investigations on fuels in progress, which as yet have led to no practical conclusions. The most important of them are perhaps the investigations on methods of manufacturing alcohol for power, in which by experiment and inquiry they are seeking to define the fundamental data on which progress in this manufacture might be made. Broadly, three classes of possible methods are known. The first and most general uses starch or sugar provided by cultivated growths, such as potatoes, mangolds or Jerusalem artichokes, or residues, such as molasses, from their manufacture; such methods are normally limited by the fact that the growths or the soil can be used with more advantage for foodstuffs. The second consists of methods of synthetic production from calcium carbide and from the ethylene furnished in the gas and coke oven industries. Here, again, calcium carbide in most places is too much needed in industry, and therefore too dear to be suitable, except possibly in districts where exceptionally cheap electric power is available; while it is questionable whether even if a manufacturing process were available for producing alcohol from ethylene, the heating value of the ethylene might not be more useful in the coal gas itself. The third class of methods, on which least has been done, but from which perhaps most is to be hoped, is the use of tropical or semi-tropical vegetation, breaking down their cellulose into fermentable bodies by chemical or bacteriological means. The work is going on, and some progress seems to have been made in the bacteriological investigation, though as yet with no results that can be applied in practice. In considering what has been done and the prospects of further work, which at present are frankly conjectural, it is impossible to avoid taking into account the enormous stake attached to a successful result. The weakness of the coal situation is that coal is a vegetable deposit, more or less difficult of access, and not to be renewed when it has been won. If alcohol could be derived cheaply and simply from tropical vegetation, the sun, which originally fostered the vegetation from which coal was formed, would provide a practically inexhaustible reservoir of power alcohol, available not in the increasing depths of mines but at grass.

Another fuel to which the Board has given considerable attention—perhaps indeed more than the value of its prospects seems to warrant—is peat. Considerable work has been done in Ireland with the Board's support or under its direction with the object of trying out methods and machinery for getting and drying peat, and some short trials made of its value as a fuel in vertical retorts. Very comprehensive inquiries have also been made in most, if not all, peat-producing countries, and a considerable amount of information has been collected, some of which has yet to be published. The standard German text book by Hausding has also been translated, though it may perhaps be questioned whether the present position of knowledge made this labour worth while. Speaking generally, it is difficult to understand the amount of attention that has been given to peat, when account is taken of its relative importance, the demonstrated technical difficulties, and the large volume of work to be done on matters of no less importance and more hopeful prospects.

Up to now the Board has done relatively little on appliances for using fuel. It has made considerable inquiry into American practice with pulverised fuel, has aided tests made at Manchester by Dr. Margaret Fishenden on domestic hearths, and Mr. A. H. Barker on cooking stoves, and at present is aiding the Manchester College of Technology in continuing Dr. Fishenden's work there under the direction of Mr. Sinnatt, while it has itself engaged Dr. Fishenden to continue her investigations at the Westminster Technical College. Doubtless this side of its work will be developed later, but the Board appears to have exercised a wise discretion in concentrating at the outset on the wider problems of production.

THE TWIN-SCREW STEAMSHIPS "ACONCAGUA" AND "TENO."

THE steamers Aconcagua and Teno were designed and built to the requirements of Lloyd's highest classification and of the British and American authorities regarding provisions for the safety of life at sea, by Messrs. Scotts' Shipbuilding and Engineering Company, Limited, of Greenock, for the Compañia Sud Americana de Vapores of Valparaiso, and are to be used on the Panama Canal route between that port and New York. The Aconcagua was put into service in the autumn of last year and the Teno followed recently. The illustrations on the three following pages, and on Plate XXXII, show the nature of the design of the vessels and the arrangement and character of the accommodation.

The hull has an overall length of 436 ft. 3 in., a moulded breadth of 56 ft. and moulded depth to the upper deck of 33 ft. The general appearance of the vessel is shown in Fig. 1, which depicts the Aconcagua at sea. The stem is straight and raked well forward, while the stern is elliptical. There are three structural decks as well as a combined poop and bridge. The designed speed was 17 knots with a shaft horse-power of 8,000, the tonnage being 7,289 gross and 3,913 net.

The trials were carried out on the Skelmorlie measured mile and proved highly successful, and the results were in close agreement with the estimated performance deduced from the experiments conducted with a model in the National Tank at Teddington. Before the trials each vessel was docked for hull cleaning. The machinery ran smoothly and there was an absence of vibration throughout the ship. The results obtained with the Teno in the progressive speed trials were :—

Speed in Knots.	Revs. per Min.	Shaft Horse-Power.
13·26	100·3	3,180
15·485	119·75	5,623
16·737	131·5	7,630
17·91	140·6	9,180

The mean draught of the vessel during the trials was 26 ft.

Accommodation is provided for 137 first-class passengers, 88 third-class passengers, 22 officers and a crew numbering 108. The general arrangement drawings, reproduced in Figs. 2 to 6, on page 489, show the location of the equipment and the relationship of the various public rooms and cabins. Essentially the vessels are designed for use as passenger vessels, but arrangements are also made for dealing efficiently and rapidly with a large quantity of cargo. The conditions of the Pacific Coast trade involve, on occasion, the loading and discharging of cargo during the night, and for that reason an installation of 10 noiseless cranes, supplied by Messrs. Fullerton, Hodgart and Barclay, Limited, of Paisley, has been fitted instead of the usual equipment of steam winches and derricks which would be objectionable under the circumstances. The locations of these cranes may be seen in Figs. 2, 3, 5 and 6 on page 489. Eight of them are 2-ton jib cranes, the two others being similar 3-ton units and thus available for lifting 6 tons on the double fall. Each crane has an outreach of 8 ft. from the side of the vessel and a lifting speed of 40 ft. per minute, when working with a hydraulic

THE TWIN-SCREW SOUTH AMERICAN STEAMSHIPS "ACONCAGUA" AND "TENO."

CONSTRUCTED BY MESSRS. SCOTTS' SHIPBUILDING AND ENGINEERING COMPANY, LIMITED, GREENOCK.

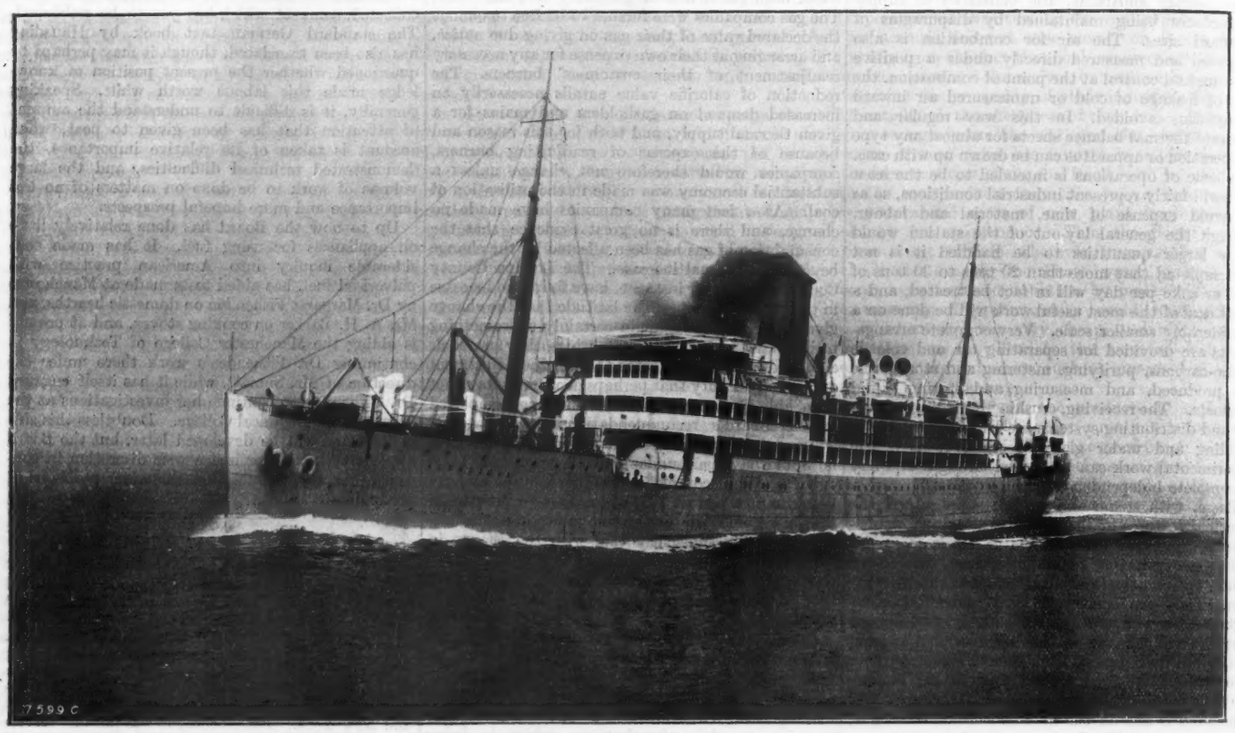


FIG. 1. THE "ACONCAGUA" AT SEA.

pressure of 1,000 lb. per square inch. When the ship is at sea adjacent cranes are hooked together by means of a forked joint and pin at the jib heads. The hydraulic supply is obtained from plant in the engine-room, driven by a three-cylinder high-pressure vertical engine. An accumulator is installed near the engine and has a control valve which operates immediately should there be a burst pipe or any sudden loss of pressure in the mains. Any crane may be isolated for repairs, and valves are provided in the engine-room to shut off either the forward or after group of cranes separately when necessary.

The watertight doors are controlled on the Scott-Ross electrical system, and the working parts of the gear are situated above the bulkhead deck, all connections being readily accessible for repairs or periodical overhauls. Ample lifeboat accommodation is provided, and includes four motor-propelled boats. All are built of teak on the double-skin system. Mechanical operating gear is fitted to all the davits.

The first-class accommodation is designed on the luxurious scale demanded in the South American trade, and occupies the mid-ship part of the vessel on the upper, bridge and promenade decks. The main staircase, Fig. 7, page 490, is panelled and painted ivory white, and an outstanding feature is its fine hand-wrought iron balustrading, the design of which was taken from the eighteenth century example in the Petit Trianon at Versailles. The monogram of the company is worked into the design of a beautifully-carved panel in the form of a wreath surrounding a finely chased old silver three-light wall candelabra.

At the after end of the promenade deck there is an open air or verandah café, Fig. 8, which is framed in trellis work for climbing plants and is furnished with comfortable cane chairs, settees and tables.

The dining room, Fig. 9, page 496, extends the whole breadth of the upper deck and provides accommodation for all the passengers at small tables. The walls are panelled in wood after the eighteenth century English period, and painted in several shades of old ivory and buff. A novel window treatment has been adopted, the frames being carried down to the floor and the lower part panelled in silvered glass, which improves the lighting of the room and also adds to the appearance of height. The furniture here is of Hepplewhite design. The large sideboard shown in the background in the illustration, Fig. 9, is surmounted with an unusual three-panelled Vauxhall mirror provided with a border of glass of a rich *gros bleu* tone, which colour is also introduced into the curtains and the chair covers. A pleasing effect is given to the table decorations by the lighting from ornamental portable electric standards having octagonal silk shades of Beige colour with light blue corners.

A very charming and elegant room is provided at the forward end of the promenade deck for use as a social hall, Fig. 10. Panelled walls of the Louis XVI period, finished in tones of French grey, carpets and curtains in a beautiful shade of *vieux rose*, and furniture. upholstered in blending colours give an attractive colour scheme. Some pieces of the furniture have their frames decorated in a soft tone of blue picked out with dull gold and provide a pleasing contrast to the general mahogany woodwork of the hall. The wall panels are broken at intervals with electric candelabra and charming old French prints framed in dull gold. A large circular dome in the middle of the roof is fitted with a hand-wrought grille or frame of iron instead of the usual leaded lights. As this room is intended to be used for dancing, the furniture is all portable and the floor is of polished oak. Gas-filled lamps with Holophane globes give well diffused and effective lighting.

The smoking room, Fig. 11, is situated at the after end of the promenade deck just forward of the verandah café. The wood panelling here is of oak, finished an old grey tone and with raised mouldings to the framing, after the style of the William and Mary period. A feature in this room is the Bolection moulded marble chimney piece which is fitted with enriched steel interior panels and a loose dog grate. Surmounting this is a carved panel, decorated with a finely-carved cartel finished in old ormolu. Wall lighting by means of electric candle brackets of the period, and furniture reproduced from fine old museum models and upholstered in antique brown hide, enhance the attractiveness of this apartment. A card room opens off the smoking room and is furnished in a similar style.

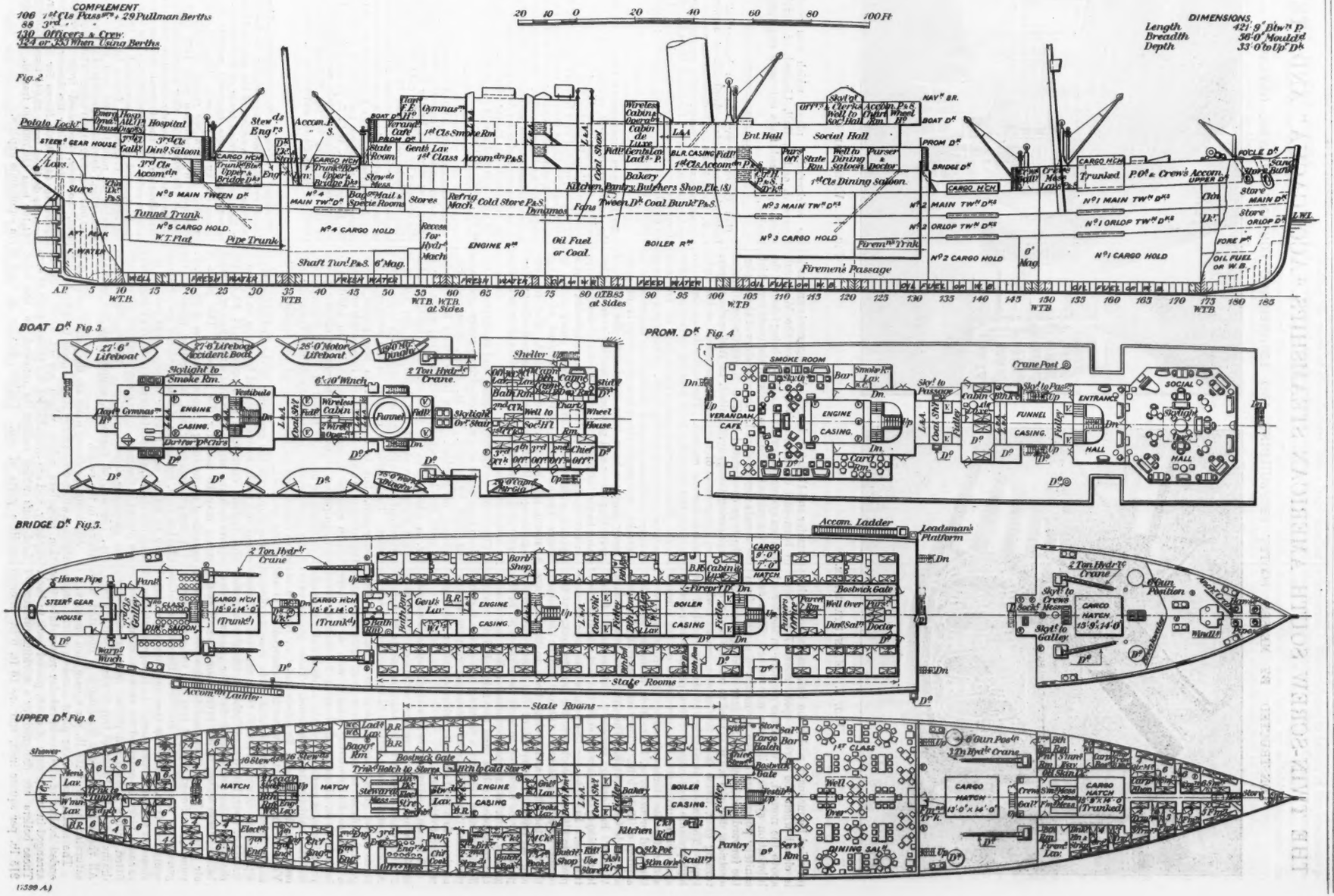
Two-light brackets with frosted, twisted flame lamps are fitted to the panels in the principal passages and stairways. The public rooms are heated electrically by means of portable units of 2-kw. sizes, and the air is circulated by ceiling sweeps and oscillating fans. For the physical recreation of the passengers there are large promenade spaces available on the bridge, promenade and boat decks, in addition to which a gymnasium, equipped with the latest devices for obtaining exercise, is provided at the after end of the boat deck.

The staterooms are all arranged so as to have access to the open air through side ports or rectangular windows. Each cabin is, in addition, provided with ventilation on the Thermotank system, a 12-in. fan being installed to assist the circulation. A bracket light over the wash basin and a separate reading light for each lower berth provide the illumination. The furnishings are on the most modern scale, and in some cases individual bath rooms open out of the cabins. Four *cabines de luxe*, Fig. 12, are provided and are decorated and furnished in the Adam style. In these cabins the berth lights are portable to permit of their use as writing table lamps; and portable electric heaters are fitted. Cooled fresh-water drinking fountains are fitted throughout. The accommodation for the captain, officers, engineers and clerical staff is in keeping with that for the first class passengers, while the crew are comfortably accommodated in rooms in the forecastle. The after end of the upper deck has been set aside for the third-class passengers, who are provided with a commodious dining saloon and have sleeping accommodation in four and six-berth rooms.

The general arrangement of the propelling machinery is shown in Figs. 13 to 19, on Plate XXXII. This equipment was constructed by the builders and consists of twin screws, each driven by a set of geared turbines of the Brown-Curtis type supplied with superheated steam at a pressure of 185 lb. per square inch. Each set of turbines comprises one high-pressure and one low-pressure unit. These run at a designed speed of 2,300 r.p.m. In the high-pressure turbine, the first stage consists of a velocity-compounded wheel with two rows of moving blades, the nine other stages being single row wheels. The low-pressure turbine has eight single-row stages, and the astern turbine, which is incorporated within the same casing, consists of two velocity-compounded wheels, which revolve in vacuo when the vessel is running ahead. The astern turbines are capable of giving 85 per cent. of the revolutions obtained when running ahead. All unbalanced axial forces are taken by thrust blocks of the Michell type. Single-reduction gearing of the double-helical type is used to reduce the turbine speed of 2,300 r.p.m. to 135 for the propellers. The main gear wheels on the propeller shafts are 10 ft. 6 in. diameter and at full power the load on the teeth is 425 lb. per inch of face width. A governor emergency cut-out arrangement is

THE TWIN-SCREW SOUTH AMERICAN STEAMSHIPS "ACONCAGUA" AND "TENO."

CONSTRUCTED BY MESSRS. SCOTTS' SHIPBUILDING AND ENGINEERING COMPANY, LIMITED, GREENOCK.



THE TWIN-SCREW SOUTH AMERICAN STEAMSHIPS "ACONCAGUA" AND "TENO."

CONSTRUCTED BY MESSRS. SCOTTS' SHIPBUILDING AND ENGINEERING COMPANY, LIMITED, GREENOCK.

FIG. 7. MAIN STAIRCASE.

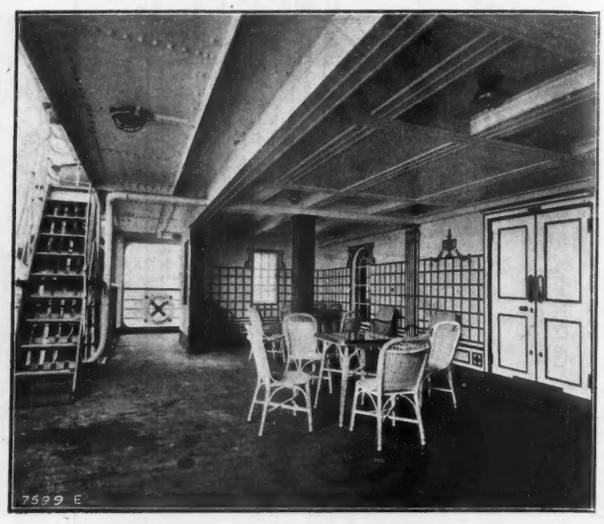


FIG. 8. VERANDAH CAFÉ.

provided by means of which the bulkhead steam valve is closed when the turbine speed rises 17 per cent. above the normal, or when the pressure on the forced lubrication system fails from any cause. Bilge and sanitary pumps are driven by means of a crank from the forward end of each main gear wheel spindle. An electric motor of 8 b.h.p. is used to operate the turbine turning gear, which is of the usual worm and wheel type. This motor is situated at the after end of the high-pressure port engine, but a portable connecting shaft with universal joints, provides a similar turning action for the starboard unit. The propellers are of the solid bronze type, 13 ft. 10 in. diameter and with a pitch of 13 ft. 9 in. They were specially balanced and made true to pitch. The shafts are provided with Vickers' lubricating system. Independent forced lubrication systems are fitted for the port and starboard turbines. In each case the pumps discharge through pressure filters and coolers to the gravity tank, but the coolers may be by-passed. Oil may also be discharged through the filters and coolers direct to the bearings and sprayers. The speed of the forced lubrication pump may be regulated to keep the level of oil in the gravity tank at a predetermined value, but should the tank become less than two-thirds full an electric float indicator actuates a warning bell at the starting platform. The oil may be discharged from the system at times to a De Laval oil purifier and after treatment returned to the tank.

The main condensers are of wedge shape and situated in the wings. They give the estimated vacuum of 27½ in., when the sea water temperature is 80 deg. F. A cooling surface of 4,000 sq. ft. is provided in each of these units. The water spaces are fitted with anti-galvanic plates to reduce corrosion. For each unit a high-speed circulating pump, with a discharge branch, 19 in. diameter, discharging 32 tons of water per minute, is used to force the cooling water through the two banks of tubes in series. These pumps were constructed by Messrs. Drysdale and Co., Limited of Yoker. The circulating water is discharged aft at an angle of about 60 deg. to the side of the vessel to obtain a propulsive effect and reduce the pump load. Messrs. G. and J. Weir, Limited, of Cathcart, Glasgow, supplied the feed water pumps and those for general service, ballast, fresh water, forced lubrication, as well as the air pumps. The engines used to drive the circulating pumps, the forced draught fans and the main electric generators are of the enclosed forced-lubrication compound type, and receive their supply of superheated steam at full boiler pressure. An independent line of exhaust pipes is provided for these auxiliaries and is fitted with a Holden and Brooke oil separator, which drains through a Bradford trap to a small settling tank. All the other auxiliary machinery is operated with saturated steam at 160 lb. per square inch pressure.

The steam generating plant consists of six single-ended boilers of the multi-tubular return-tube type arranged in two groups of three, placed back to back. These boilers are designed for a working pressure of 215 lb. per square inch, and are 16 ft. 6 in. internal diameter and 11 ft. 9 in. length. Arrangements are made to burn coal or, alternatively, oil on the Wallsend-Howden system, to permit advantage being taken of the varying prices for the two fuels on the route for which the vessels were designed. Superheaters of the smoke-tube type constructed by The North-Eastern Marine Engineering Company, Limited, of Wallsend-on-Tyne, give a superheat of 150 deg. F. measured at the high-pressure turbine casings. The boiler tubes are 3 in. diameter and there is a total heating surface of 17,800 sq. ft. When burning coal with 5 ft. 3 in. fire-bars, the total grate area is 385½ sq. ft. The pipe system is arranged so that any one of three of the boilers may be operated independently when the ship is in port. Tracey purifiers have been fitted with the object of preventing water and grit being carried over with the steam to the turbines. An ash ejector of the See type has been furnished in each of the two stokeholds, and is supplied with water from a duplex pump made by Messrs. Thom, Lamont and Co., Limited, of Paisley. A steam ash hoist is also installed. For fire extinguishing in the boiler room a large fire foam plant is provided in addition to the usual hand-type fittings for incipient fires.

Electricity for lighting, heating and ventilation is obtained from three 40-kw. steam-driven engine generator sets built by Messrs. W. H. Allen, Sons and Co., Limited, of Bedford. The three units are needed to meet the load when all the heating units are in use, in addition to the lighting. The lighting installation comprises about 900 lights, and the wiring is carried out on the double-wire system with lead-covered cables. The wiring is clipped to the surface in the staterooms, but is concealed in the public rooms. Distribution is controlled at large fuse panels or switchboards erected under the stairways. In addition to this equipment there is an emergency electric power installation to meet the Board of Trade requirements. A fire alarm system is fitted throughout the ship; this gives indications on the bridge of the location of the section involved.

The ship, with the exception of the first-class staterooms and public rooms is heated by steam on the two-pipe system, distributed at a pressure of 10 lb. per square inch and arranged so that either live or exhaust steam may be used for the purpose. This plant is capable of maintaining a temperature rise of 50 deg. F.

A fire-extinguishing and fumigating plant of the Clayton type, by means of which sulphur gas or steam may be led to each hold or to any other part of the ship, is installed, and portable chemical fire extinguishers are placed in the most convenient positions throughout the passenger accommodation. Messrs. Shanks and Co., Limited, of Barrhead, supplied all the sanitary fittings in the vessel.

Adjoining the dining room are the pantry and galley, through which direct entry is obtainable to the refrigeration chambers below, which are of 5,000 cub. ft. capacity, and are available for the preservation of such food-stuffs which cannot be renewed at the intermediate ports of call. Carbon dioxide is used in the refrigerating plant, which was constructed by Messrs. J. and E. Hall, Limited, of Dartford. Electrical equipment finds extensive employment in the kitchen.

GAS CALORIMETRY.—In his lecture at the Royal Institution on Friday, April 27, at 9 p.m., Professor C. V. Boys, F.R.S., will describe his recent work on the recording gas calorimeter, which promises to be of great service to engineers. Professor Boys is, of course, one of our greatest experimentalists, being one of the few who are capable of weighing and measuring quantities on the verge of the imponderable.

SOCIÉTÉ DES INGÉNIEURS CIVILS DE FRANCE.—On the occasion of their seventy-fifth anniversary, the Société des Ingénieurs Civils de France are holding special meetings from May 4 to 6. On May 4, the meeting will be presided over by the President of the Republic, when papers will be read on metallurgy and electricity. On May 5, papers are to be read dealing with wireless telegraphy and aeronautics. There are to be visits to, and receptions at, the aeronautical station at Le Bourget, at the Conservatoire des Arts et Métiers, the Eiffel Tower, the Gennevilliers Power Station, the Ecole Centrale. The members and guests will meet at a dinner on May 6, at the Palais d'Orsay.

THE GENERATION AND UTILISATION OF COLD—The discussion on the "Generation and Utilisation of Cold" which was arranged by the Faraday Society, joined on this occasion by the British Cold Storage and Ice Association, and held on October 16 last, was noticed at some length in our issue of October 20 last, abstracts of some of the papers following in our further issues of October 27 and November 3. The full report on the general discussion has now been published by the Faraday Society, 10, Essex-street, W.C. 2, at the price of 10*s.* 6*d.* The volume of 273 pages contains some further contributions to the discussion by Dr. Richard Linde, Munich, Mr. Georges Claude, Paris, and Mr. K. S. Murray.

FOREIGN TRADE OF SWITZERLAND.—The Commercial Secretary at Berne has forwarded to the Department of Overseas Trade a review of the principal items of interest in last year's foreign trade of Switzerland, in which he states that imports exceeded exports by 225,000,000 francs, *i.e.*, by 16·9 per cent. (In 1921 by 23·2 per cent., in 1920 by 22·8 per cent.) Although coal imports increased in comparison with 1921 (220,000 tons, as against 163,000 tons), they represented only two-thirds of the quantities yearly imported prior to 1914. The electrification of the Federal Railways contributed to a large extent in this reduction. The total value of the coal imported in 1922 amounted to 147,000,000 francs, as against 171,000,000 francs in 1921. Whereas the number of manufactured iron goods introduced into Switzerland decreased, imports of pig-iron had risen from 163,000 tons to 230,000 tons. The value of these articles had, however, decreased from 45,000,000 francs to 27,000,000 francs, for the former and from 51,000,000 francs to 44,000,000 francs for the latter. Machinery imports declined from 29,045 tons (57,000,000 francs) to 24,100 tons (36,700,000 francs). There was also a fall in automobile imports.

NOTES ON NEW BOOKS.

Among text books, those of an elementary nature call for the greatest care in their preparation. Beginning from fundamental principles, a knowledge of the subject must be imparted to the reader, such as he can build on as his experience grows. On the basis of his first-acquired perceptions he must be able to interpret the actions of more intricate and involved matters. If his early training be thorough, he will have little difficulty in using it later, and in recognising the orderly and systematic growth of progress made in the subject. Looked at from that standpoint, the writing of an introductory manual must be regarded as an effort demanding the exercise of the greatest ability. The elementary books on science and technology issued by the University Tutorial Press seem to have been written by people who have that point of view. For students who are not attending classes they serve a very useful purpose in an efficient way. The recent issue of a new edition of the "*First Course in Heat Engines*," by J. W. Hayward (4*s.* net), may be cited as an example. In this are to be found not only references to lecture-room demonstrations relating to engines and their operation, but the student is also introduced to many simple experiments, which can be performed with home-made apparatus. The advantage of this to the student, who has to rely more or less on his own resources, is obvious. The matter is well illustrated with diagrams, and contains examples and exercises. One small point should be noted for alteration in any future edition. Coal-gas is regarded from the standpoint of yesterday. The calorific values stated relate to what is an almost unknown product. The flaw is a small one, but the stated calorific values and composition of town's gas should be more in keeping with the actual conditions of modern practice, if the student is not to have exaggerated notions of the heat values.

It is often found difficult to understand why the subject of mechanics does not appeal readily to the average student. Mr. J. F. S. Ross, lecturer on engineering at Loughborough College, in a work entitled "*An Introduction to the Principles of Mechanics*," published by Mr. Jonathan Cape, London, at 12*s.* 6*d.* net, suggests that much of the distaste evinced by students of the subject owes its origin to the use of unsuitable methods of teaching. The steering of a middle course between the formalistic and academic methods of applied mathematics and the undue emphasis of practical details in the usual treatment of applied mechanics, presents many difficulties. Mr. Ross has aimed at producing such a work and in his endeavour has very largely succeeded. Any student of ordinary capacity may obtain a clear understanding of the general principles of the subject of mechanics, as well as a grasp of the methods of applying them, from this work. The aim of making the student think rather than learn is shown throughout the treatment. For all theoretical purposes absolute units are employed, which has many advantages. This is in keeping with the works on theoretical mechanics and in common with some of the best teachers on applied mechanics. In any treatment from first principles, the introduction of conversion factors to put the results into the units of common usage in practical work should follow after the consideration. Dr. William Garnett, who wrote the introduction to the book, lays stress on teachers of mechanics, warning students against the use of rules and formulæ unless they clearly understand their derivation and significance. To those who have had experience of teaching, the unreasoning use of easily remembered expressions by students has shown the many pitfalls awaiting the unwary. For all who really desire to obtain a clear understanding of fundamental principles as a foundation for their future work this book may be recommended.

The design and construction of American machines, in the construction of which mass production is used, has great interest for the British engineer. Motor car manufacture is an example, and the publication by the McGraw-Hill Book Company of a book on "*Automobile Power Plants*" (15*s.* net), by Professor Ben G. Elliott, of the University of Wisconsin, is to be welcomed as bringing together descriptions of the various engines used in American cars. In this work all the components of the engines are described and their construction and assembly discussed. Accessories are also referred to, and engine cooling and lubrication are reviewed at length. There is an unfortunate omission from an equation for the brake horse-power of an engine (on page 18), which is obviously due to an undetected printer's error. The designs shown reflect the differing outlooks of American and British engineers on the question of mass production. Where there is a dearth of skilled workmen, the cheap production of a motor car engine is largely a question of design, the conditions of which are dictated by the necessity for dividing the work of manufacture into a large number of operations of an exceedingly simple character, and involving very few manual movements. Conditions in America suited the development of this activity, while those operating in Britain hindered its application. The sudden adoption of any great change in workshop methods was almost impossible in Britain. Gradually the outlook has changed, and improved methods have been introduced from time to time, and motor car production has now become a real manufacturing process, although it cannot be said that design for cheapness in production has been carried to the extremes effected in America. Much of the difference in design of British and Continental motor car engines, and those produced in America, which are illustrated and described in Professor Elliott's book, is due to the difference of attitude towards production methods.

The increasing interest that is being taken in the subject of jigs and fixtures is evidenced by the fact that a second edition has been required of "*Jigs and Fixtures*," by Fred. H. Colvin and Lucian L. Haas (McGraw-Hill Publishing Company, Limited, London, E.C. 4; 12*s.* 6*d.* net). The subject is handled in 16 chapters, in which details of design and construction are treated at length, with cognate matters. The first 10 chapters are occupied strictly with the subject denoted by the title, the remaining six deal with gauges, vice jaws, mandrels, boring bars and heads. The first chapter describes the evolution of a jig in the tool room, showing how the various elements are determined and detailed, to be approved by the chief tool designer, the tool-room foreman, and the superintendent, and how the standard elements are selected and applied in the production of a jig, and the operation sheets prepared. Lists of the several elements, and dimensions, are tabulated. The different kinds of jigs are classified in Chapter II, the illustrations being good perspective views. A large variety of forms is given, and many are additions in the new edition. A short chapter describes the locating schemes for drill jigs, and another gives many examples of standard bushings, with tables, and dimensions. Details of other kinds are drawn in the fifth and sixth chapters—hinged lids, locking lids, jack screws, pins, stops, indexing pins, wedges, cam locks, clamps, fasteninga, thumb screws. A summary of points to be considered in designing, with questions, include all conceivable possibilities. Jig clamps and clamping methods occupy Chapter VII, with many examples, some being introduced in this edition. Milling fixtures have a chapter to themselves, pneumatic fixtures another, and a dissertation on the latch jig occupies Chapter X. Chapters XI to XIII deal with gauges of snap, ring, plug, thread, limit and other forms, abundantly illustrated, and with many tables of standard dimensions. Machine vice jaws, mandrels, boring bars and heads and reamers are treated very fully in the remaining chapters. A vast amount of valuable information is compressed into this volume of 237 pages, and over 450 good line drawings. We can recommend it with confidence to the men in the tool-room and to shop managers.

The initial difficulties that many mechanics of imperfect education encounter when confronted with formulæ will be lessened by a study of a treatise on "*Shop Arithmetic for the Machinist*," by Erik Oberg, (5*s.* net), which is issued by the Machinery Publishing Company, Limited, London. A knowledge of common arithmetic is assumed, but not any acquaintance with mathematical formulæ. The examples selected relate to the problems that call constantly for solution. They include tapers, screw threads, speeds of gears and pulleys, chain gears, indexing, belting, times required for drilling, milling and planing, areas and volumes, specific gravities and weights. The use of tables of sines, cosines, tangents and cotangents is explained, to enable those who have no knowledge of trigonometry to apply its formulæ. The methods of obtaining square and cube roots are given, with examples. It should prove a most useful handbook for the class of men for whom it is written, who are in the majority in the shops.

The atomic theory was formulated by Dalton during the first decade of the nineteenth century, but fully 100 years had to elapse before it was universally accepted. Indeed, it was not officially countenanced in the French elementary schools until 1895, and twenty-five years ago there was still an influential section who maintained that the development of the science of energetics made it possible and desirable to dispense with the hypothesis altogether. A curious philosophical question arises in this connection. Some writers seem to claim that our belief in the existence of, say, an iron rod has a basis different in kind from that which leads us to believe in the existence of an atom of iron. As a matter of fact, both existences are equally hypothetical, being both deductions from experience. The evidence in favour of the one assumption is qualitatively identical with that in favour of the other; the difference being quantitative merely. Amongst those who have so notably increased the amount of evidence in favour of the atomic theory, a leading place must be assigned to Professor J. Perrin, and Mr. Hammick's translation of Professor Perrin's treatise on "*Les atomes*" constitutes a most valuable addition to our scientific literature. This translation has been published by Messrs. Constable and Co., under the title "*Atoms*," the price of issue being 8*s.* 6*d.* net. In this book Professor Perrin gives a full account of his researches on the Brownian movements, by which he proved that the small particles exhibiting this phenomenon must, from the physical standpoint, be regarded simply as molecules, obeying the laws of the perfect gas. In fact, every particle suspended in a fluid, whether large or small, must be so regarded, but when the mass is large the chance of a perceptible motion being brought about by bombardment by the molecules of the fluid becomes vanishingly small. For example, a brick suspended from a rope in air might, Professor Perrin calculates, be thus moved through a perceptible height once in 10^{10} years. The small particles of gamboge suspended in water with which Professor Perrin experimented were moved through distances comparable with their dimensions every few seconds. Maxwell showed many decades back, that the second law of thermodynamics was contingent merely, and that an organism capable of dealing with individual molecules could evade it, and devise a "perpetual motion machine of the second kind." Professor Perrin points out that in the case of the large "molecules" constituted by his particles of gamboge, a bacterium could deal with the individual particles and thus defeat the second law. Every now and then the particle is jerked upwards, and if seized at the top of its path, the bacterium could accumulate particles which had been raised from a lower level, and which would then constitute a store of energy obtained in violation of the second law of thermodynamics. Another very interesting section in the book is that in which Professor Perrin suggests that dissociation is never the direct result of molecular impacts—but is to be attributed to the action of radiation, just as is the shooting out of a corpuscle from a metal by ultra-violet light or the impact of X-rays. This suggestion seems to have been first made by Sir J. J. Thomson in the 'eighties of last century, and Professor Perrin notes several more recent partial anticipations of this theory at which he independently arrived. As was pointed out in ENGINEERING, January 21, 1921, page 63, the theory provides a very simple physical explanation of the fact that most gases are cooled by expansion through a porous plug. Another highly interesting suggestion is made by the author in regard to radioactivity. He enters a *caveat* against the view that radioactive bodies are confined to the mere crust of the earth, a theory which is based on the observation that were the whole body of the earth as radioactive as the crust the outflow of heat should be much greater than it actually is. The radioactive bodies are for the most part very heavy, and would thus naturally gravitate to the centre. Whilst in our laboratories it has been impossible to vary the rate of radioactive change, it seems practically certain that this arises merely from the limitation of our resources, and Professor Perrin suggests that an endothermic formation of the radioactive bodies may be taking place in the interior of the earth. He also suggests the possibility that the break up of the radio-active atoms is not really spontaneous, but is due to an encounter with X-rays of extraordinarily penetrative power, emitted from these deep levels. One other point may be mentioned. When radium breaks up, it liberates the helium nuclei which constitute the α-rays, and which in view of their extraordinarily high velocity can be detected as individuals. At the same time the emanation, niton, is produced. The atom of this, being of very high mass, acquires but little velocity, and it would thus be impossible to detect a single atom of this gas. There is thus the possibility that atomic transformations are taking place which we have no means of detecting, since unless the products of the decomposition give rise to swift rays, the disintegration would pass unperceived.

NEW EMPIRE STADIUM, WEMBLEY PARK.—During February and March, 1923, Messrs. David Kirkaldy and Son carried out tests upon portions of the Stadium. The tests were made chiefly by the application of some thousands of sand bags, and by the marching of men over the structure. On an area intended to accommodate 2,000 spectators, a load of sand equal to the weight of 4,000 people was applied, and no signs of weakness were observed. Staircases and barriers were subjected to a similar intensity of loading with equally satisfactory results. Messrs. Kirkaldy are of opinion, from the results of their observations, that the Stadium is of adequate strength to carry safely a far greater number of spectators than it can possibly hold.

THE LORING MACHINE FOR ADDING LIQUIDS TO POWDERS.

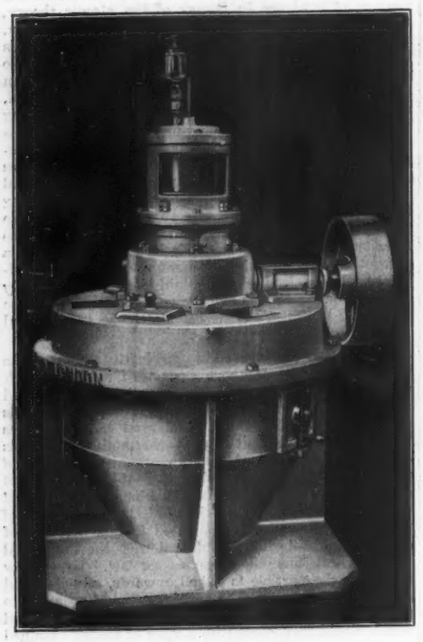
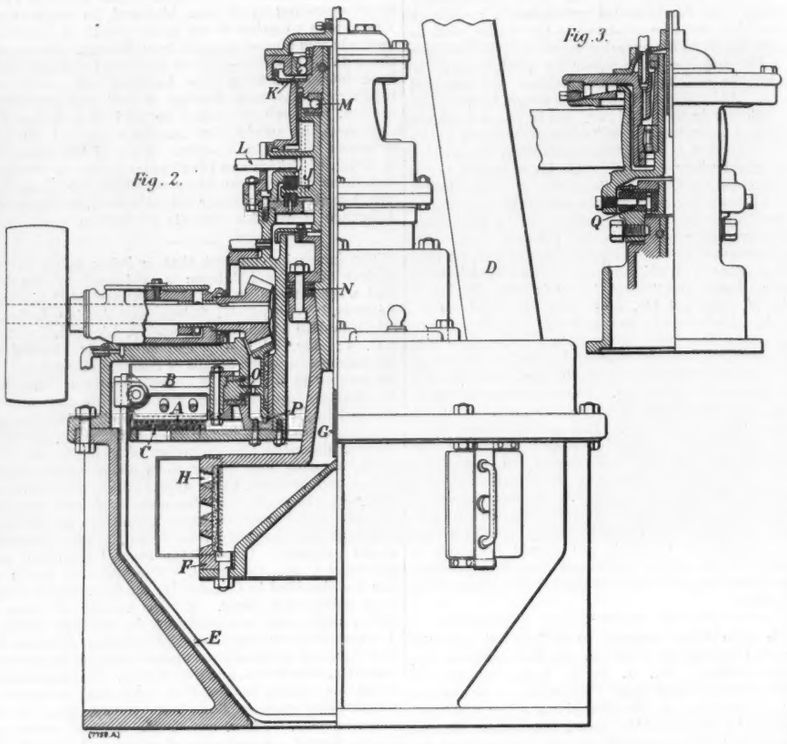
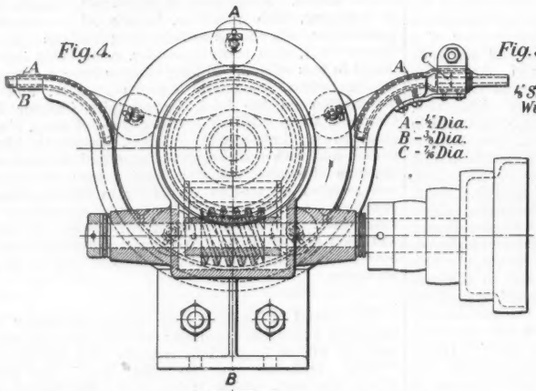
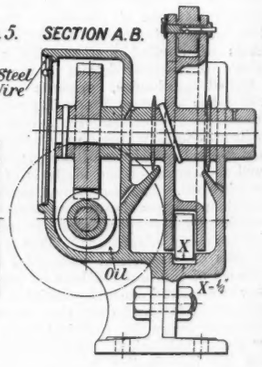
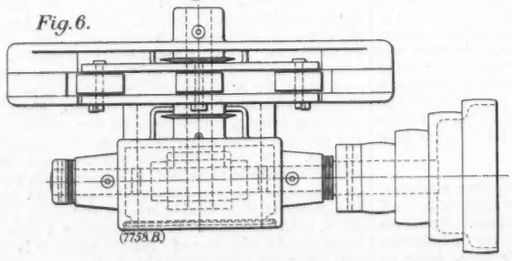


Fig. 1.









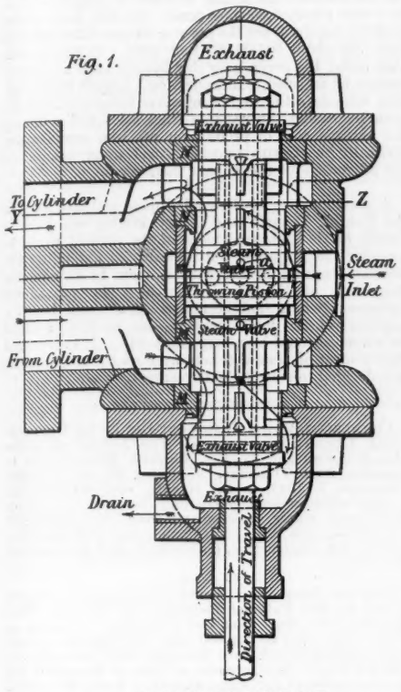
The addition of liquids to pulverised substances is not such an easy problem as at first sight might be imagined, especially when a uniform treatment is to be maintained over considerable periods. The first method which suggests itself would probably be one involving the use of a spray, the material being sifted in front of it by means of a reciprocating sieve. In this case, the difficulty of obtaining a uniform treatment throughout the material may, in a measure, be overcome by making the apparatus rather large and not attempting to add much liquid to the powder; but even then the arrangement is not sufficiently satisfactory to be regarded as a final solution of the problem. The material falling nearest to the spray orifice receives more treatment than the material falling at points further away. Moreover, in this spray method, in which compressed air is used in order to get the desired fineness of spray, a considerable amount of air is of necessity blown into the chamber into which the material falls. This air has to be got rid of, and, while this is not in itself a difficult matter, there is the possibility of the escaping air carrying along with it fine particles of the material which is being treated. Dust collectors can, of course, be used, but this apparatus adds to the complication of the plant. When a process of this kind is maintained in continuous operation day and night it is surprising to note how much material can escape by leakage in this manner. It is often desirable to apply the liquid in what might be termed a closed-in circuit and, when air-liquid sprays are used, "blowing" at all crevices in the system is the result.

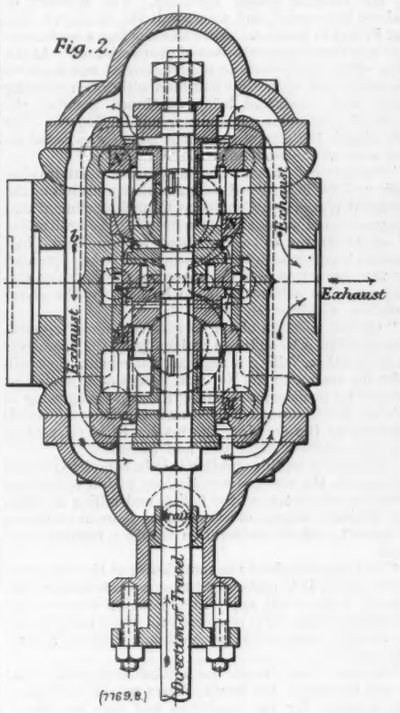
The idea of using centrifugal force to introduce the liquid directly into the falling material, thus avoiding the introduction of air, having occurred to Mr. F. H. Loring, of 30, Norfolk-street, Strand, W.C. 2, the machine illustrated in Figs. 1 to 6, which appear on this page, was developed and has been in successful operation for some time.

To throw the liquid directly into the material when in a state of fine subdivision would seem to be the most natural solution of the problem; and the device adopted for throwing the liquid takes, in the machine, the form of a perforated basket lined with thick felt. This basket is whirled in the falling material, the liquid delivered inside it being sprayed on the inner side of the felt lining through which it passes. In order to break up the liquid so finely that it is hardly visible as a spray, it is necessary to rotate the basket at high speed. For a basket 16 in. in outside diameter a speed of from 2,000 r.p.m. to 2,500 r.p.m. is desirable in order to obtain perfect treatment of the material. The powdered material under treatment does not adhere to the outside of the basket, which is rotating directly in it. The powder is sifted round the basket by means of a revolving brush passing over a wire grid which is in reality a sieve. This sieve is made by coiling a wire on the face of a plate, perforated with large holes. The coils of wire are bound together and fastened to the plate by means of a few cross-laced wires and clips, soldered. The brush bristles sweep between the wires, keeping the mesh open whilst spreading the material on the surface of the grid or sieve so as to distribute it uniformly round the basket. The liquid is centrifugally sprayed against the felt lining of the basket by introducing indentations at intervals on the surface of a cone which forms the basket bottom. The liquid is delivered on to the apex of the cone by means of a stationary tube extending down the hollow spindle carrying the basket.

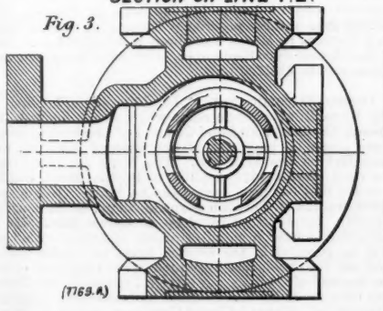
The following detailed description of the apparatus will be found of interest since it is the manner in which details have been worked out that has made the machine a practical success. A general view of the machine is given in Fig. 1, while Fig. 2 shows it partly in vertical section and partly in elevation. Fig. 3 shows an alternative form of high speed driving gear, also in part section and part elevation. We will consider first the powder distributing arrangements. The brushes A, Fig. 2—usually there are six of these—are fixed to radial arms B, which are driven by means of bevels, a short shaft, and a belt pulley. The ring carrying the arms revolves round a central trunk, and is supported by the ball bearing P. The brushes revolve within an annular cover, in which openings are arranged to admit the powdered material to them as they pass over and sweep through the grid C constructed in the manner already described. One of the wooden spouts for

LOCKWOOD'S VALVE FOR DIRECT-ACTING FEED PUMP.





SECTION ON LINE Y.Z.



conveying the powder into the machine is shown at D. The form of construction adopted results in a continuous opening all the way round the circumference of the grid, the grid itself being supported by studs from the central trunk. The clearance between the grid and the walls of the machine allows a U-shaped sweeper bar E to be fixed to, and to revolve with, the brush arms. This bar is carried round the inside of the hopper and keeps the powdered material from accumulating on the walls. The circular grid is surrounded by a low rim of sheet metal, and a ring of thin plating to match, is fixed to the brush arms. A small space is left between these rings, and through this some of the powder tails over into the hopper below. As this falls near to the walls it keeps the latter dry and prevents excessive accumulation on them of treated material.

Turning to the provision made for delivering the liquid, this is passed into the rotating basket F by means of the tube G, which is clamped in position so that its bottom end is just clear of the apex of the cone-shaped bottom of the basket. The liquid from the tube drops on the surface of this cone and runs down it until it comes across an indentation, when it is thrown off by centrifugal force in the form of a spray. The indentations are arranged round the cone in circular rows. The spray of liquid is thrown up against the felt liner through which it finds its way in a very finely divided state, and into the space inside the hopper surrounding the basket, passing through holes H in the side of the basket. The interior parts of the basket and all passages are lined with vulcanite when it is desired to use the machine for certain corrosive liquids, in which case the body of the basket may be cast in steel.

One of the special features of the machine consists in the provision of a non-rigid suspension form of high-speed bearing for the vertical hollow spindle from which the basket is hung. The spindle is carried by the ball bearing M, which is supported by a sleeve with three circular flanges. The upper flange takes the supporting ball race, whilst the lowest of all, J, is held between two rubber rings, giving the non-rigid support required, the rubber rings being carried by the central fixed trunk already referred to. The middle flange of the three acts as a tray to catch any surplus oil from the ball bearing. In order to steady the drive and at the same time relieve the main bearing of some of the side pull of the belt, a grease-lubricated spherical ball bearing K is provided. This is housed in a casing and cap mounted on the upper part of the fixed trunk. The inner race of the ball bearing is secured to the belt pulley boss which in turn is fixed to the spindle by two pins. In the lower part of the boss the top race of the bearing M is placed. The pulley proper extends downwards so as to shroud the bearing. The oil for this bearing is fed through an oil pipe L and a duct leading up to the bearing. Oil passing downward through the main sleeve bearing is caught by a collar and oil thrower, and delivered to a well formed in the surrounding casting, whence it is drained away. Felt washers N, with spacers of metal serve to make a fairly dust-tight seal in the trunk itself. In order to keep dust out of the gear drive for the brushes felt washers O are held in place in grooves in the revolving brush gear, and run in matching grooves in the fixed part of the machine. This provides a seal but allows the revolving part to float freely.

Doors are furnished in the hopper for inspection and cleaning purposes. A thin cover plate is introduced to prevent the material caking up on the inner part of the conical bottom of the liquid distributor. To ensure lubrication of the bearing of the bevel wheel to which the brush arms are fixed, without having to apply an excess of oil to it, two wipers of felt are let into grooves as shown, cut approximately parallel with the vertical axis of the machine.

Fig. 3, as already stated, shows an alternative type of top drive in which the pulley is arranged centrally with respect to a spherical ball bearing held in place by a sleeve depending from the top casing. The pulley in this case has an extended lower rim through which pins project towards the inside, into a rubber block Q which in turn is held firmly to the part to be driven by a set of small vertical pins and a clamping nut, the drive being through the flexible connection thus provided.

The operation of the machine will be apparent from the foregoing description, but it may be noted that, in falling, the particles of the powdered material follow a spiral course due to the whirling of the basket, and each is brought into intimate contact with the vapour-like spray leaving the basket.

One of the most difficult problems in connection with this method of adding liquids to powders in small regulatable quantities, was to devise a positive feeding appliance which would deliver a precise quantity of liquid regardless of any variation in basket pressure or suction arising from the operation of the basket. Small gravity feeds, with restriction tubes, plunger pumps, &c., were tried, but troubles soon developed. In the plunger pumps the small valves sometimes ceased to function on account of particles sticking to the seats. All difficulties were, however, overcome by a method of rolling out a soft rubber tube through which the supply is fed. Figs. 4, 5 and 6, which show how this arrangement was worked out, explain themselves. In principle, of course, the device is not new. In Fig. 4 a section showing the worm drive has been superposed on the other parts. The four-step pulley gives a drive allowing a considerable range of feed which can be maintained at a definite and constant amount. Certain acids which attack rubber cannot be handled by this device, but it is surprising how many salt solutions and acids can be used with it without resorting to filters, and even syrupy liquids can be fed through this apparatus, which has now been in use for many years without giving any trouble. The rubber tube (actually consisting of one tube within another) can be renewed at trivial cost, but such renewals are infrequent as the rolling of the rubber does not seem detrimental to the tube. A tube may be expected to last for two months of continuous day and night service. If water is used in the machine it is necessary to utilise a tank supply instead of drawing direct from the mains, in order to avoid the pressure of the mains. The tank can be placed conveniently a few feet above the level of the machine.

VALVE FOR DIRECT-ACTING FEED PUMP.

WE illustrate on this page a valve for a direct-acting feed pump, the design of which is due to Mr. P. W. Lockwood, of 145, Shields-road, Glasgow. It has been fitted on board a large Atlantic liner, with, it is stated, very satisfactory results. With this valve applied to the vertical type of pump, the pump is claimed to be self-starting under all conditions.

The valve is designed to be operated by the usual type of lever gear, supplemented by the action of a steam "throwing" piston which comes into operation so soon as the lever gear has nearly opened the valve for making a return stroke. At this stage the steam "throwing" piston comes into operation and throws the valve wide open, thus preventing short stroking or non-operation. The principle is, of course, not new, but Mr. Lockwood's design embodies certain novel features. Each valve, whether steam or exhaust, is at once a piston valve and a seated valve. In the fully closed position the valve in fact seats itself, thus ensuring tightness, and only acts as a piston valve during the change over at the end of each stroke. The change-over period is of very short duration, and consequently no very high degree of tightness is necessary when the valve is acting as a piston valve. It is thus possible to dispense with internal lubrication

Longitudinal sections through the valve chest are represented in Figs. 1 and 2 and a cross-section in Fig. 3. The steam admission valves with the "throwing" piston between them occupy the middle portion of the steam chest. As represented in Fig. 1 the valve is admitting steam to the top of the cylinder. The lower steam valve is at rest on its seat as is also the upper exhaust valve, whilst the lower exhaust valve is wide open. As the piston approaches the end of its stroke the lever gear is operated by the tappets, and moves the valves up into the position indicated in Fig. 2. In this position the piston portion of the valves working in the bushes M and N respectively, close both ends of the cylinder both to steam and to exhaust. This motion of the valves has, however, brought the hole shown at *a*, Fig. 1, into the position shown at *b*, Fig. 2, and as will be seen the steam above the "throwing" piston has now a clear escape through this hole to the exhaust port by the passage shown. As a consequence the "throwing" piston is moved up by the steam below it and completes the stroke of the valve.

The pump to which the above valve has been fitted was a large one, the steam cylinder being 13½ in. in diameter by 26 in. stroke. It supplies the feed for engines indicating 6,000 h.p

THE SENTINEL STEAM WAGON WORKS AT SHREWSBURY.

BY the invitation of the directors of the Sentinel Steam Waggon Works (1920), Limited, a party of guests visited the Shrewsbury Works of the company on April 12 for the purpose of inspecting the processes of manufacture and witnessing demonstrations of the "Super-Sentinel" steam wagon which was illustrated and described in our last issue. The Sentinel wagon was first built in 1906, at Glasgow, by Messrs. Alley and McLellan, Limited, who started the Shrewsbury

works for its manufacture in 1915. The works are situated on the outskirts of the town, and opposite them is a "Garden City" built by the company for the accommodation of its workmen. The houses on this estate are all electrically lighted and heated with radiators, besides being provided with an unlimited supply of really hot water from the works at all hours. Heat is furnished by the exhaust steam from the works engines, which passes into calorifiers, the hot water from which is pumped through the works for heating and washing purposes, and also through the houses. Of these there are at present 100, which were put up by the company under the Ministry of Health housing scheme to mitigate the acute house shortage in Shrewsbury caused largely by the advent of the company. The scheme comprises an ultimate number of 400 houses, all with two sitting rooms, and either three or four bedrooms.

The works, which now give employment to between 700 and 800 workmen, are being extended to accommodate about 1,100, when the capacity will be 50 complete wagons per week with normal hours of work. The factory, as may be imagined, is of the most modern description, consisting of single-storey buildings with saw-tooth roofs, and arranged that a continuous run of work takes place. The line and countershafting is all mounted in Hoffmann ball bearings, and the main shafts are driven by overhead electric motors, driving through silent chains. Power, light and heat are derived from the company's power-house, which contains two pairs of 100-kw. 220-volt direct-current generators, each pair driven in tandem by a Belliss engine, and four "Sentinel" air compressors made by Messrs. Alley and McLellan, Limited, driven by the new type of "Super Sentinel" wagon engines. These latter engines have now been running continuously for about four years.

The works contain a large number of single-purpose machines, and the system of jigs is thoroughly worked out. The engine camshafts are made by grinding direct from the bar, the cams being formed by a copying motion derived from a master camshaft. After the cams have been roughed out in this manner, the shaft is heavily case-hardened and the cams are then finished by grinding in the same machine. Practically the whole of the manufacturing processes are carried out on a straight piece-work system. A certain proportion of the finished engines are submitted to careful dynamometer tests, and their performances accurately determined. Every completed wagon, before leaving the works, undergoes a lengthy test on a special dynamometer brake driven by the rear road-wheels. These wheels rest on drums which absorb the power by driving a dynamo, and other drums geared to the former support the front wheels of the vehicle, which are thus kept running under load. A crossbar fastened to the piston of a pneumatic cylinder, enables any load from 4 tons to 10 tons to be put on a wagon during test. The horse-power developed at the rim of the road-wheels, and also the road speed, are indicated by the readings of the instruments employed. The minimum test which a wagon must pass before leaving the works is equivalent to a non-stop run of 4 hours fully loaded up an incline of 1 in 7. After this a short road test is all that is requisite, so that the roads in the neighbourhood of the works are not unduly worn by wagon tests.

In connection with the works, the laboratories must be mentioned. There are both chemical and mechanical laboratories, with a weighing-room between. These departments are not kept for show purposes, but are a definite factor in the works activities. Five per cent. of all material entering the works is tested in an appropriate manner, as a matter of routine, and special tests are always in progress. The equipment includes a fatigue testing machine designed and constructed by the firm, in addition to microphotographic apparatus and testing machines of usual types. Another department characteristic of a modern factory is the canteen, which has seating accommodation for a thousand men. Here good and well-cooked meals are available for the employees at extremely moderate prices. Staff dining rooms are also provided.

BRITISH CHAMBER OF COMMERCE, PARIS.—This Chamber of Commerce which was established in 1873, celebrates this year the fiftieth anniversary of its constitution. On this occasion, a banquet is to be held, probably on May 4, at the Hotel Continental, Paris, and it is hoped that as many members as possible will attend.

BUNKER COAL INSPECTION IN THE UNITED STATES.—Inspection and sampling of coal purchased by the United States Shipping Board in New York for its steamship lines will be carried out by the Department of the Interior through its Bureau of Mines. The work is to include sampling of foreign coal remaining in bunker upon the arrival of the ships in New York, as well as sampling the coal while it is being loaded on the vessels in the New York port.

INDUSTRIAL NOTES.

A VERY satisfactory change has occurred in regard to the building trades' difficulty. The Ministry of Labour intervened, and as a result the employers met last Friday in London. After this meeting a conference was held with representatives of the operatives. At the close of the conference an announcement was made to the effect that the notices had been withdrawn, existing wages and conditions being continued pending the result of arbitration upon the points in dispute. The following is the official statement which was issued on the work of the conference:—

"Conditional upon the employers withdrawing their notices, it is agreed that the interpretation of the National Wages and Conditions Council document and the question of wages shall be referred to the arbitration of an arbitrator to be appointed by the Lord Chief Justice, together with two assessors, one to be appointed by the operatives and the other by the building employers. The arbitration is to be held on the above questions within seven days.

"On the question of the forty-seven hours' application, a ballot is to be taken regionally by the operatives as to whether, failing a regional settlement, they will refer the matter to the National Wages and Conditions Council for decision, and failing the regions agreeing to this or the National Wages and Conditions Council agreeing on the decision, the matter to be referred to the above-named arbitrator and assessors.

"The ballot on this question is to be completed within one month, the regional negotiations within seven days after the completion of the ballot, and failing decision, the National Wages and Conditions Council to decide or agree to refer to arbitration within a further seven days.

"In the principle of the spread-over of the forty-four hours' week, it is understood that no extension of the present hours would apply in any region where unemployment in the crafts is excessive. Each party agrees to conduct arbitration proceedings without a legal advocate."

The Lord Chief Justice has notified both parties that he has appointed Sir Hugh Fraser as the arbitrator. The assessors for the employers and men are Mr. J. Greenwood and Mr. A. Cameron, respectively.

The conference upon overtime and night shifts between the Shipbuilding Employers' Federation and representatives of the Federation of Engineering and Shipbuilding trades, referred to in our last issue, was held last Friday. At the close it was announced that the action of the boilermakers and joiners had been reviewed, and that a special meeting would be held on the following Wednesday (the 18th inst.), at which the matter would be further considered. In the meantime the number of boilermakers who decline to work overtime and on night shifts is increasing.

A communication made by a number of cotton trade unions, and having reference to the stabilisation of wages, was considered at a conference of employers and operatives, held in Manchester last Friday. The wages agreement now in force expires on the 25th inst., and either side can give one month's notice of a change in the list rates. It is reported that the Operative Spinners' Amalgamation and the Operative Weavers' Amalgamation propose that the agreement be extended for twelve months; hitherto, the Cardroom Operatives' Amalgamation are not at one with the other unions on the point. The employers met the Legislative Council of the Textile Factory Workers' Association last Tuesday in Manchester.

Meetings of the Whitley Council have had under consideration the dispute in the printing trade, to which we referred on page 473 *ante*. No basis for a settlement has so far been arrived at, and the matter has been left for the consideration of the unions. It is reported that the joint secretaries of the Whitley Council are to convene a further meeting as soon as it is considered desirable.

A report recently issued by Mr. Philip Gee, 40, King-street, Covent Garden, W.C.2, states that the total coal output for the fifty-two weeks ended March 24, 1923, was 260,641,900 tons, a deficit of 26,769,969 tons on the 1913 figure. The average weekly output during those fifty-two weeks was 5,012,344 tons, a deficit of 514,807 tons on the weekly average of 1913; and yet there are 40,000 more men now employed in and about the coal mines than was the case in 1913. In view of these figures, it is quite obvious that a six-hour day, which means a working day of four and a-half hours at the coal face, is utterly impracticable. It may be that the proposals for a further restriction of the length of the working day below ground in mines are intended merely as an answer, in default of more effective argument, to the case which is being presented by the owners for a return to the eight-hour day underground, which would give a working day of six and a-half hours at the coal face, instead of five and a-half as at present. It was calculated before the war that the normal average annual increase in coal consumption was about 5,000,000 tons. On this basis there would be required, not the pre-war output of 287,000,000 tons, but about 50,000,000 tons more. It is apparent that under the seven-hour day system such a demand cannot be satisfied. Increased coal output would not only stimulate the revival of other industries, but by both increasing the receipts from sales and reducing the average cost of production per ton, would automatically react with two-fold effect upon wages, to the advantage of the miners themselves.

A mass meeting of the coal tippers and trimmers in the Cardiff, Penarth and Barry Docks, was held in Cardiff at the commencement of the present week, to consider the proposals put forward for extending the present working hours, with a view to relieve the congestion at the loading berths. The provisional agreement which had been arrived at—and had the approval of the men's leaders—for working a third shift was rejected by a large majority. It is reported that a meeting was also held at Port Talbot, when it was decided to accept the agreement.

COMMERCIAL MOTOR TRANSPORT AND ROADS DEVELOPMENT EXHIBITION, OLYMPIA.—The Society of Motor Manufacturers and Traders, Limited, have decided to organise, from Thursday, November 22, to Saturday, December 1, 1923, in the recently enlarged Olympia, an exhibition embracing not only the various types of commercial motor vehicles and their components and accessories, but also plant, machinery and materials used in the construction, maintenance and development of roads.

BRITISH IRON AND STEEL PRODUCTION.—Figures issued by the National Federation of Iron and Steel Manufacturers show that the production of pig-iron in March amounted to 633,600 tons, the highest monthly production attained since January, 1921 (when it was 642,100 tons). The furnaces in blast at the end of the month numbered 202, an increase of 13 during the month. The production includes 206,300 tons of hematites, 204,600 tons of basic, 144,700 tons of foundry, and 45,900 tons of forge pig-iron. The output of steel ingots and castings in March amounted to 802,500 tons, which is the highest since September, 1920, when the production amounted to 884,700 tons.

DIESEL-ELECTRIC SHIP "LA PLAYA."—The first of the three Diesel-electric ships which are being built by Messrs. Cammell Laird and Co., and of which some details were given on page 472 of our issue of April 13, was launched on the 17th inst. The boats are being built for the United Fruit Company, of Boston, Mass., U.S.A., and the first has been named the La Playa. Her dimensions are 325 ft. between perpendiculars, 48 ft. moulded breadth, by 31 ft. 9 in. deep to upper deck. She is designed to have a speed of about 14 knots. The boat will be engaged in the banana trade in tropical zones, and all her holds are insulated with cork and cooled on the cold-air system. A large refrigerating installation has been made by Messrs. Hall, and an electro-hydraulic capstan of Messrs. Clarke-Chapman make is fitted, together with eight electric cargo winches by the Sunderland Forge Company, and an electro-hydraulic steering gear by Messrs. Hastie. As explained in our earlier notice, the boat is fitted with four Cammellaird-Fullagar Diesel engines driving dynamos connected in series. A single propelling motor is mounted aft. Speed control is obtained entirely on the field circuits and the main circuits have never to be broken. The electrical equipment is being supplied by the British Thomson-Houston Company.

RILEY COMBUSTION FILM.—Mr. Charles Erith, A.M.I.Mech.E., exhibited on the 11th inst. to a largely-attended meeting of the Electrical Power Engineers' Association at Liverpool University, a moving picture showing the actual processes of combustion in a large modern boiler, at loads varying from banked fires to about 9 lb. of steam per square foot heating surface. The boiler was fitted with a Riley moving-grate, retort-type stoker, carrying a thick bed of fire, the incandescent surface of the entire fuel bed radiating direct to the boiler tubes, as no furnace arches are required with this firing system, in which the fuel bed is progressively advanced, and the incombustible ash is continuously discharged, at all rates of combustion, by the Riley conveyer-tuyeres or moving grates. Reference was made to the very large Riley stokers in British, French, American, Indian, Australian, Chinese and Japanese central stations, under all types of water-tube boilers. Mr. Erith described the methods of protecting the lens of the camera, whereby it has become possible to obtain a satisfactory picture of combustion at a furnace temperature of 3,000 deg. F. The actual motion of the coal through the furnace was clearly illustrated on the film. This showed how, in only 6 minutes, starting from banked fires, the rate of combustion was increased until the boiler duty was brought up to 70,000 lb. steam hourly, or about 9 lb. actual steam per square foot, corresponding to 300 per cent. on American boiler rating, by merely increasing the speed of the Riley stoker, and varying the draught pressures of the fans. Mr. Erith invited all who wished to see the Riley film exhibited in London, to communicate with him at Palace Chambers, Bridge-street, S.W. 1.

MONEL METAL.*

By JOHN ARNOTT, A.I.C.

THE subject, "Stainless and Non-Corrodible Alloys," covers a considerable range, hence it may be well at the outset to indicate the place which Monel metal occupies. Monel metal may be said to be primarily an engineering material with excellent physical properties, and good resistance to many corrosive agencies. Its sphere of use is therefore different from that of the truly acid-resisting metals, such as the iron-silicon alloys, which have to be employed in certain cases in spite of their poor mechanical properties.

The composition and physical properties of Monel metal are now fairly well known. In the hot-rolled condition it has the following properties (average figures):—

Proportionality limit	...	16 tons per sq. in.
Yield-point ...	...	21 tons per sq. in.
Tensile strength ...	...	40 tons per sq. in.
Elongation ...	...	35 per cent.
Reduction of area	...	65 per cent.
Brinell hardness ...	...	160.

The resistance to impact is very high. The writer has not had any specimens of hot-rolled metal break in a 120-ft.-lb. Izod machine. Usually over 110 ft.-lb. are absorbed in bending the test-piece. Cold-rolled and cold-drawn metal are now used to quite a considerable extent. In small diameter rod and in wire, the tensile strength can be increased to over 60 tons per square inch. There are reports from service that the cold-drawn metal is more resistant to certain solutions than hot-rolled, and laboratory tests are now being carried out to verify this. As is to be expected from the high nickel content, the heat conductivity of Monel metal is low, about 7 per cent. of that of copper. An important property of the metal is the retention of strength and ductility at temperatures above normal. At 750 deg. F., the highest steam temperature in use in this country, Monel metal retains 85 per cent. of its normal strength.

TABLE I.

Acid.	Strength.	Temp.	Hours.	Loss: mg./dm.²	Thousandths of an Inch Removed.
Sulphuric	10 per cent. by volume of 1·84 sp. gr. ..	Room	2,000	1,130	0·5
Sulphuric	10 per cent. by volume of 1·84 sp. gr. ..	B.P.	300	2,840	1·3
Sulphuric	1 per cent. by volume of 1·84 sp. gr. ..	Room	2,000	1,320	0·6
Sulphuric	1 per cent. by volume of 1·84 sp. gr. ..	B.P.	300	3,120	1·4
Hydrochloric	10 per cent. by volume of 1·16 sp. gr. ..	Room	2,000	2,410	1·1
Hydrochloric	10 per cent. by volume of 1·16 sp. gr. ..	B.P.	200	6,690	3·0
Hydrochloric	1 per cent. by volume of 1·16 sp. gr. ..	Room	2,000	2,310	1·0
Hydrochloric	1 per cent. by volume of 1·16 sp. gr. ..	B.P.	300	2,980	1·3
Nitric ..	10 per cent. by volume of 1·42 sp. gr. ..	Room	2,000	2,220	1·0
Nitric ..	10 per cent. by volume of 1·42 sp. gr. ..	B.P.	6	11,600	5·2
Nitric	1 per cent. by volume of 1·42 sp. gr. ..	Room	2,000	1,470	0·6
Nitric	1 per cent. by volume of 1·42 sp. gr. ..	B.P.	100	6,300	2·8
Acetic ..	10 per cent. by volume	Room	2,000	1,130	0·5
Acetic ..	10 per cent. by volume	B.P.	200	1,670	0·7
Sulphurous	5 per cent. of H_2SO_3 ..	Room	300	9,910	4·4
Phosphoric	1·35 sp. gr.	Room	2,000	271	0·1
Oleic ..	As sold commercially ..	170° C.	100	180	0·1
Stearic	As sold commercially ..	170° C.	100	237	0·1

TABLE II.

Alkali or Salt.	Strength.	Temp.	Hours.	Loss, Mg./dm.²
Sodium hydrate ..	10 per cent. ..	Room	2,000	8·0
Sodium hydrate ..	10 per cent. ..	B.P.	300	4·0
Ammonium hydrate	10 per cent. by volume of 0·880 sp. gr.	Room	1,100	Nil
Sodium chloride ..	10 per cent. ..	Room	2,000	36·0
Sodium chloride ..	10 per cent. ..	B.P.	300	127·0
Calcium chloride ..	20 per cent. ..	Room	200	3·0

Atmospheric Corrosion.—Monel metal is very little affected by exposure to fairly pure air. A sheet freely exposed to the elements at Cathcart was bright after five months and showed no change in weight. In air which is more impure, Monel metal becomes discoloured, but the attack does not extend beyond the surface layers. Sheets exposed in the east end of Glasgow and in Coatbridge, districts which are close to large steel works, both lost weight to the extent of 15 mg./dm.² after five months. The brown discoloration on each is easily removed by a fine abrasive.

Sea Water.—The resistance of this metal to sea water may be said to be practically absolute. Several valves which have been in actual sea water for over three years are as bright as when first immersed.

Steam.—Monel metal is unaffected by wet, saturated or superheated steam. Valves working in steam at 750 deg. F. for several years are only slightly dull on the surface and clearly show the original tool marks.

Resistance to Acid.—Generally, Monel metal is not suitable for use with strong acids, as in acid manufacture. It is readily soluble in concentrated nitric acid, and is attacked by strong hydrochloric and sulphuric acids, especially if the acids are impure. The effect of various acids at different strengths and temperatures is shown in Table I. All the tests were carried out on pieces of sheet 3 in. by 2 in. by $\frac{1}{16}$ in. thick, weighing roughly 50 gm. The sheets were in rolled condition and were not polished but simply cleaned to remove traces of grease. Sheet was chosen because it affords a large surface for a given weight. The tests were carried out in pairs, one at room temperature, the other (except where otherwise stated) at a temperature between 90 deg. C., and the boiling-point of the liquid. The acid or other liquid was replaced by a fresh supply in accordance with the rate of attack. The sheets were weighted at short intervals in cases of rapid corrosion, and every 100 hours in cases where the rate of attack was slow. The loss in weight has been calculated to mg./dm.², and also in terms of the number of thousandths of an inch removed. The latter method has proved useful in estimating the probable life of specific articles under given conditions.

It will be noted that in both sulphuric and hydrochloric acids the rate of corrosion is almost the same for 10 per cent. and 1 per cent. solutions. It will also be noted that sulphurous acid attacks the metal violently. A solution containing only 2 per cent. of H_2SO_3 removed 2,540 mg./dm.² in 100 hours, leaving the sheet deeply pitted and covered with a black deposit, which was largely sulphide. With the exception of sulphurous acid all the other acids left the sheets clean and free from any deposit. The effect of several alkalies and salts is shown in Table II.

Monel metal is not affected by alkalies and only to a slight extent by the majority of solutions of neutral salts at ordinary temperatures. Throughout the tests given above and many more which were made with solutions used in specific industries, no evidence was found of selective action to any appreciable extent. The graphs of loss of weight plotted against time are almost straight lines. Only in the case of oleic and stearic acids were the specimens "coppered" on the surface.

To sum up, Monel metal is suitable for parts which have to resist (1) sea water, (2) impure water such as is found in many canals and in mines, (3) steam, (4) dilute acid solutions, such as are used in many industrial operations, (5) alkaline solutions of all kinds.

The writer is indebted to the directors of Messrs. G. and J. Weir for permission to publish the data in this paper.

* A contribution to a general discussion on "Alloys Resistant to Corrosion," held jointly at Sheffield by the Faraday Society, the Sheffield Section of the Institute of Metals, and the Manchester Metallurgical Society, Friday, April 13, 1923.

FOREIGN TRADE OF SWEDEN.—The issue of *The Swedish Economic Review* for the first quarter of the current year, contains much interesting information in the foreign trade of Sweden. A map shows the bulk of that country's foreign trade in 1921 with various other countries, from which it is seen that the most important interchange of commodities took place with the United Kingdom, followed by Germany and the United States. Another map gives the location of the various industries in Sweden. The pamphlet can be obtained from the Swedish Consulate-General in London, Bank Chambers, 329, High Holborn, W.C. 1.

CONTRACTS.—The Powdered Fuel Plant Company, Limited, of 47, Victoria-street, S.W. 1, have received an order for firing with powdered coal, by means of their turbo-pulverisers, five Clarke-Chapman "Woodeson" boilers for the owners of the Pelton Colliery, Limited. The boilers are two of 15,000 lb. and three of 8,000 lb. per hour evaporation, and seven turbo-pulverisers are being installed, two to each of the larger boilers and one to each of the smaller ones. They will be driven by electric motors through enclosed gears. Coal bunkers and coal-handling plant are also being supplied by the above company, who have also received orders for three separate unit plants during the last few days for the firing of one water tube boiler and two metallurgical furnaces.

THE BRITISH CAST-IRON RESEARCH ASSOCIATION.—The Special Committee working upon the standard test bar specification have decided upon a basis for drawing up a national specification. Agreed points have been arrived at and it is expected that a preliminary report will be issued at an early date. The work of internal-combustion engine castings research is being pushed forward, castings defective in design and manufacture are being examined, and the investigation is being carried out both on the engineering and metallurgical side. A draft specification for air-cooled and jacketted cylinders for automobiles has been considered and approved. The shrinkage defects research has broadened out to include the whole of the fundamental properties of cast-iron, such as liquid shrinkage, solid contraction, physical properties, corrosion, &c. The preliminary report will shortly be issued to members and will contain very valuable data upon this trouble common to all foundries. The association have under consideration specifications for cast-iron for piston ring pots, and also for concentric piston rings, which have been prepared in co-operation with the British Engineering Standards Association. Problems sent in by members continue to be dealt with. During the past month the membership of the association has very materially increased.

NOTICES OF MEETINGS.

THE WEST BROMWICH ENGINEERING SOCIETY.—Friday, April 20, at 7.30 p.m., at the Technical School (near the Town Hall). Paper, "Superheated Steam and Superheaters," by Mr. T. A. Pain, A.M.I.Mech.E., Wolverhampton.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, April 20, at 6 p.m., at Storey's Gate, St. James's Park, S.W. 1. Hardness Tests Research. "Static Indentation Tests," by Mr. R. G. C. Batson; "The Relation between Width of Scratch and Load on Diamond in the Scratch Hardness Test," by Mr. G. A. Hankins, A.R.C.Sc. Friday, April 27, at 7 p.m.: Informal Meeting. Adjourned discussion on "The Use of Light Alloys in Place of Iron and Steel," by Mr. A. E. L. Chorlton, C.B.E.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Friday, April 20, at Bolbec Hall, Newcastle-upon-Tyne. "Possibilities of Increased Efficiency in Railway Locomotives," by Mr. T. Grime.

THE MINING INSTITUTE OF SCOTLAND.—Saturday, April 21, at 3 p.m., the forty-sixth Annual Meeting will be held in the Royal Technical College, George-street, Glasgow. The new president, Professor Robert W. Dron, will be introduced and inducted to the chair; Professor Dron will deliver his presidential address. The following papers will be open for discussion: "The Mining of Two Seams in Close Proximity," by Mr. R. A. Macdonald, B.Sc.; "Tests of Centrifugal Ventilators, with Special Reference to Initial Water Gauge," by Mr. Henry C. Harris, B.Sc.; "Tacheometry as a Method of Underground Surveying," by Professor Henry Briggs, D.Sc., and Mr. James Cooper, F.R.S.E.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Monday, April 23, at 7 p.m. Informal Meeting. Discussion on "Practical Broadcasting," to be opened by Mr. E. H. Shaughnessy, O.B.E.

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, April 24, at 6 p.m. Annual General Meeting of Corporate Members only, to receive the Report of the Council, and to elect the Council and Auditors for the ensuing year.

THE INSTITUTION OF AUTOMOBILE ENGINEERS.—Tuesday, April 24, at 7.30 p.m., at the Railway Hotel, Coventry, Mr. E. B. Wood will read a paper entitled "Sleeve Valve Engines," before the members of the Institution. The chair on this occasion will be taken by Dr. F. W. Lanchester. Mr. E. B. Wood will also read his paper before the Scottish Centre on Monday, April 23, at the Royal Technical College, Glasgow, at 7.30 p.m., and before the Wolverhampton Centre at The Star and Garter Hotel, Wolverhampton, on Wednesday, April 18, at 7.30.

THE ILLUMINATING ENGINEERING SOCIETY.—Tuesday, April 24, at 8 p.m., at the House of the Royal Society of Arts, John-street, Adelphi, London, when a discussion on "Some Problems in the Lighting of Printing Works" (Compositors' Benches, Machining Room, Colour Printing, Proof-reading and Editorial Departments, &c.), will be opened by Mr. Leon Gaster.

THE INSTITUTION OF LOCOMOTIVE ENGINEERS (LONDON).—Thursday, April 26, at 7 p.m., at the Engineers' Club, Coventry-street, W. 1, "The Coaling of Locomotives," by Mr. L. P. Parker, Member, London.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, April 27, at 7.30 p.m., at 39, Victoria-street. Lecturette: "Stock Control," by Mr. J. Fearn (Member).

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, April 27, at 9 p.m., a discourse will be delivered by Mr. C. V. Boys, F.R.S., M.R.I. The subject is "Measurement of the Heating Value of Gas." Afternoon Lectures, at 3 p.m.: Tuesday, April 24, Sir Arthur Keith, M.D., LL.D., F.R.S., Sec. R.I., Fullerian Professor of Physiology, on "The Machinery of Human Evolution: (III) How New Features are Gained"; Thursday, April 26, Professor J. T. MacGregor-Morris, M.I.E.E., M.R.I., on "Modern Electric Lamps: (I) Glowing Solids in Vacuo (Tungsten Lamps)." Saturday, April 28, Mr. Leonard Williams, M.D., M.R.I., on "The Physical and Physiological Foundations of Character" (Lecture I).

BROWN-BOVERI ELECTRIC FURNACE.—The new metallurgical furnace of Messrs. Brown, Boveri and Co. is designed for working with either three-phase or single phase currents. There are two upper vertical electrodes, separately adjustable, and a fixed third electrode embedded in the hearth, all three in the same vertical plane. The furnace body is a horizontal cylinder of iron lined with refractory material and resting in trunnions in a semi-cylindrical cradle. The upper electrodes are fixed to two standards which are connected with the cradle in such a way that the electrodes need not be removed when the furnace is tilted; on the other hand the whole body can be taken out of the cradle when renewal becomes necessary. The electrodes are graphite rods, generally 4 in. or 5 in. in diameter; the fixed electrode only is water-cooled. The furnace is run with the aid of a transformer which for furnaces of charges of 200 kg. or 300 kg. may have to supply up to 140 K.V.A. In order to reduce the heavy current fluctuations which the melting of cold charges involves, a three-phase choking coil is inserted into the connections. Furnaces of this type have been installed in the foundry of the firm and in other metallurgical works, including the metal works of Selve and Co., the Swiss Locomotive Works, Winterthur, the Roll Iron Works in Clus, and also the Federal Mint in Bern, for melting alloys, copper, nickel, bronze, silver, iron and steel.

THE TWIN-SCREW SOUTH AMERICAN STEAMSHIPS "ACONCAGUA" AND "TENO."

CONSTRUCTED BY MESSRS. SCOTTS' SHIPBUILDING AND ENGINEERING COMPANY, LIMITED, GREENOCK.

(*For Description, see Page* 487.)

FIG. 9. FIRST-CLASS DINING SALOON.

FIG. 10. SOCIAL HALL.

FIG. 11. FIRST-CLASS SMOKING ROOM.

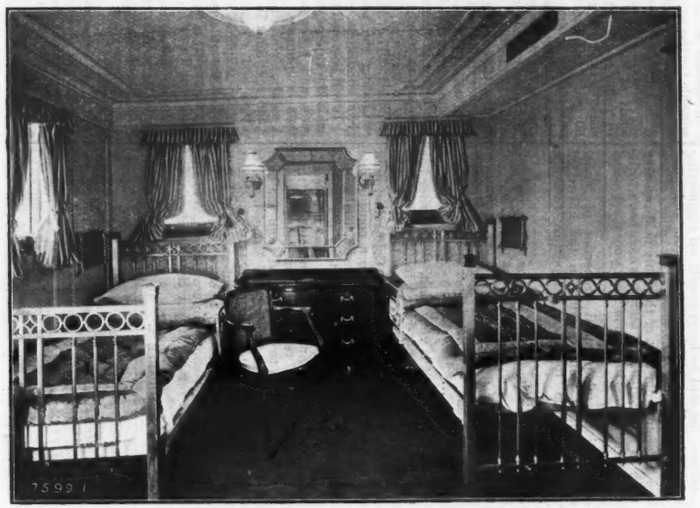


FIG. 12. CABIN DE LUXE.

FIG. 11. FIRST-CLASS SMOKING ROOM.

FIG. 12. CABIN DE LUXE.

GENERAL ARRANGEMENT OF GEARED TURBINE MACHINERY AND

CONSTRUCTED BY MESSRS. SCOTTS' SHIPBUILDING AND E

(For Descriptio, see Pa

Fig. 13. ELEVATION AT CENTRE LINE OF SHIP. LOOKING TO PORT.

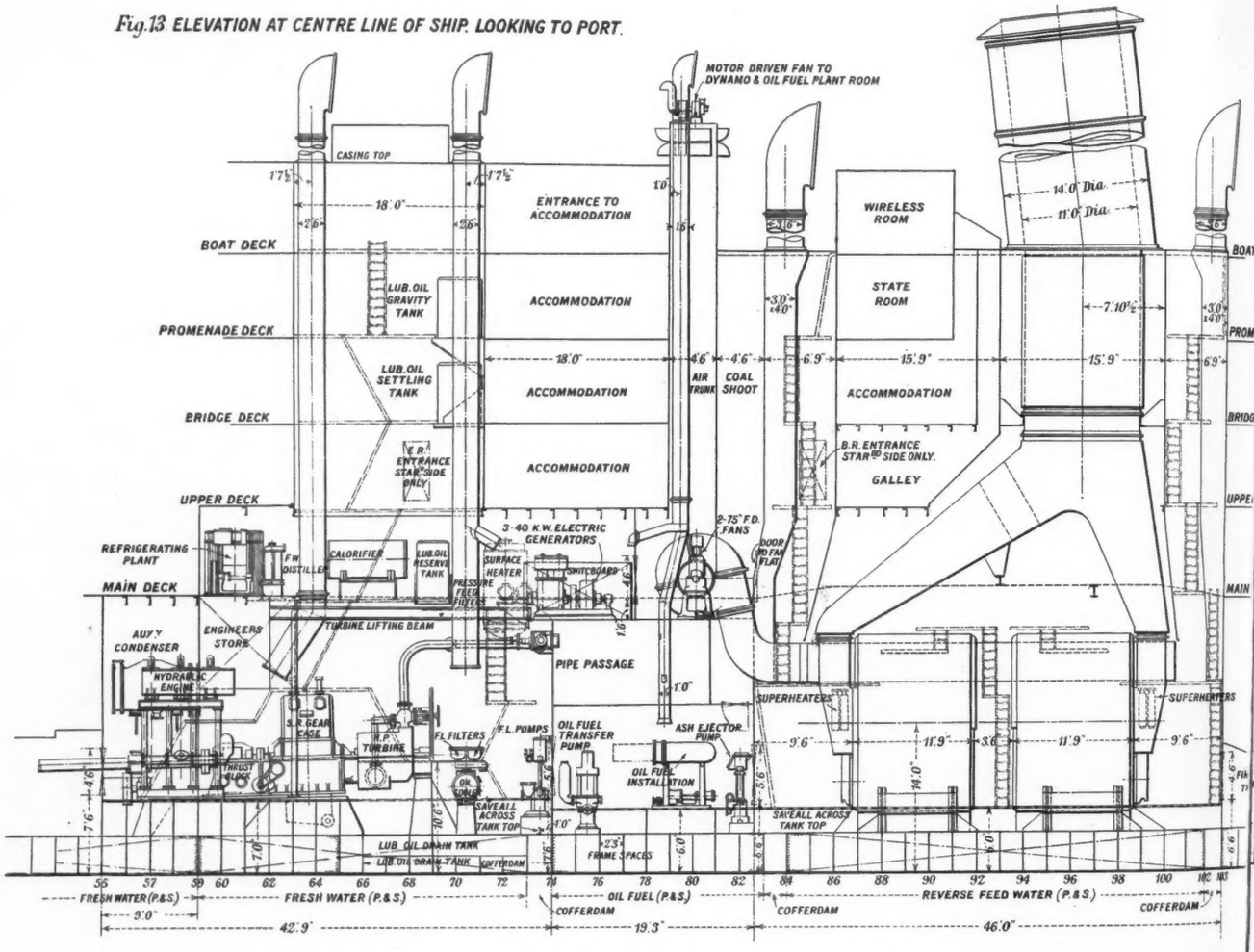
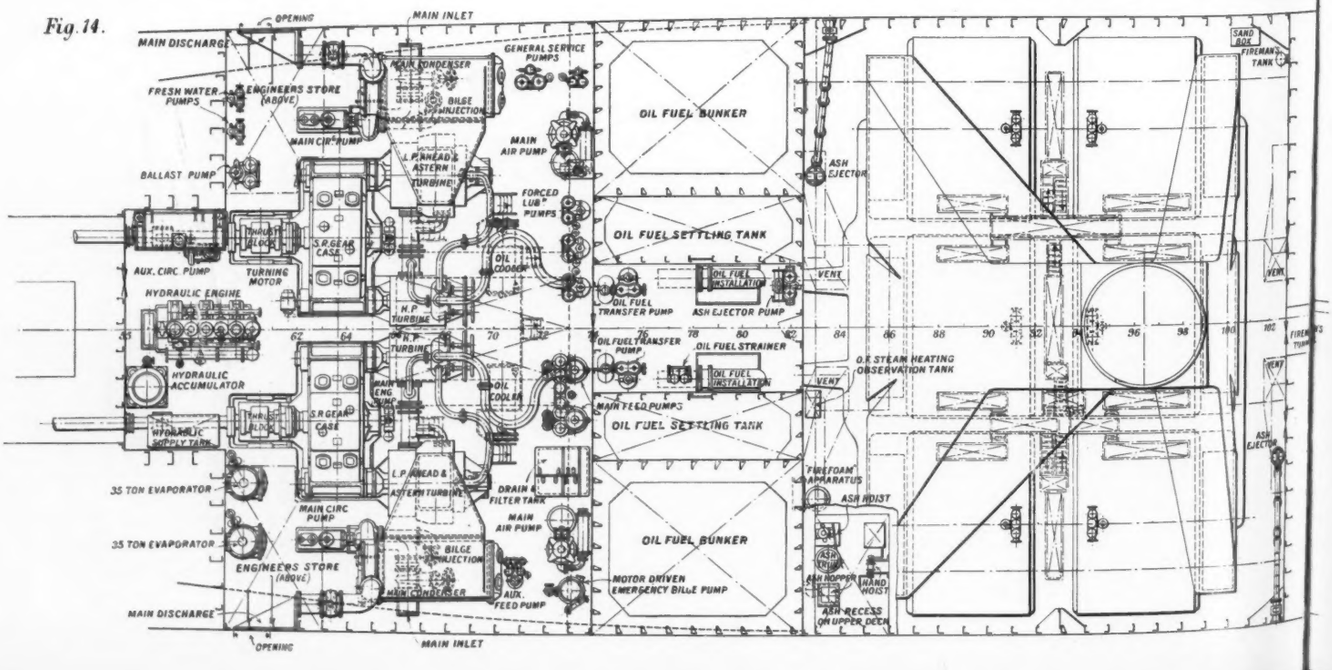


Fig. 14.



RY AND BOILERS OF THE STEAMSHIPS "ACONCAGUA" AND "TENO."

BUILDING AND ENGINEERING COMPANY, LIMITED, GREENOCK.

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Fig. 15. SECTION AT FRAME 84. LOOKING FORWARD.

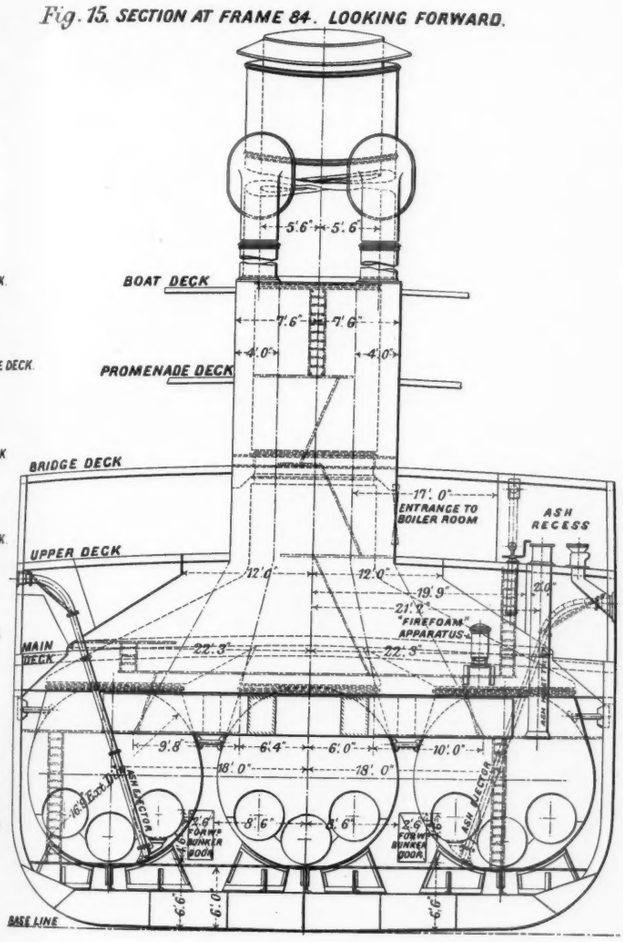


Fig. 16. SECTION AT FRAME 82. LOOKING AFT.

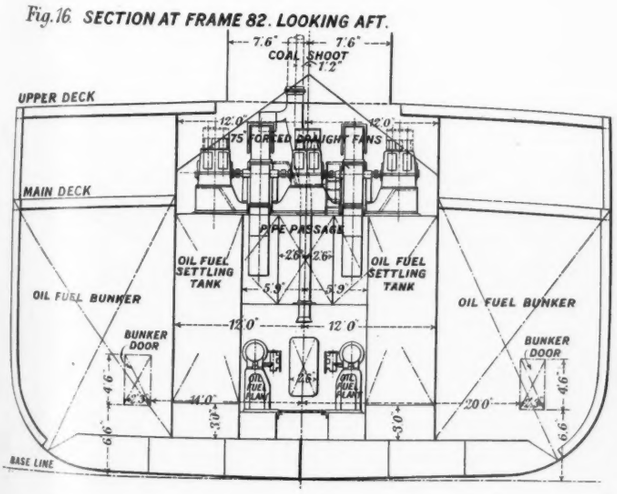


Fig. 17. SECTION AT FRAME 73. LOOKING FORWARD.

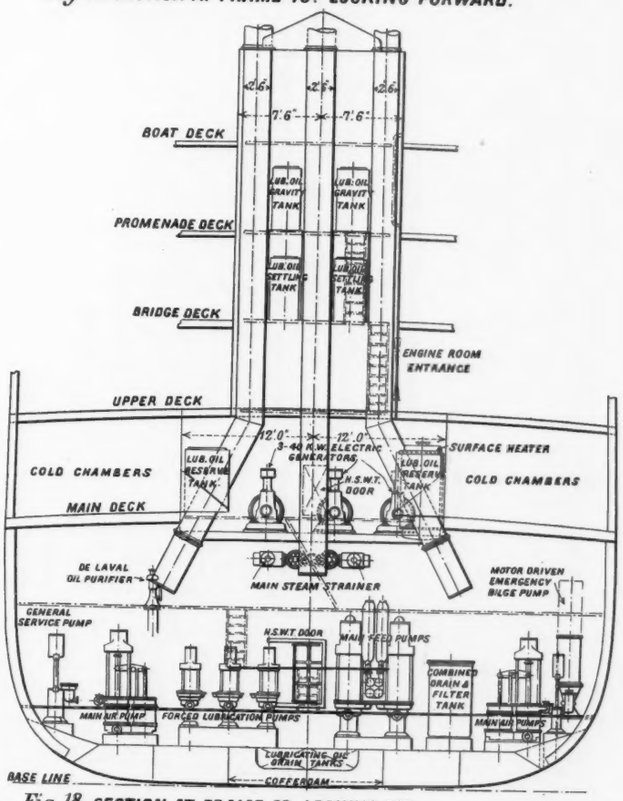


Fig. 18. SECTION AT FRAME 63. LOOKING AFT.

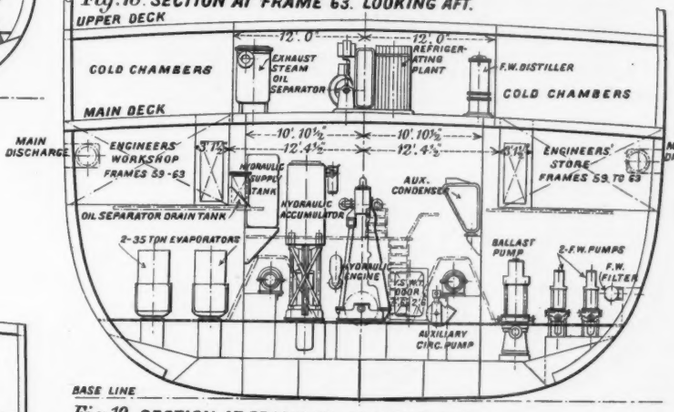
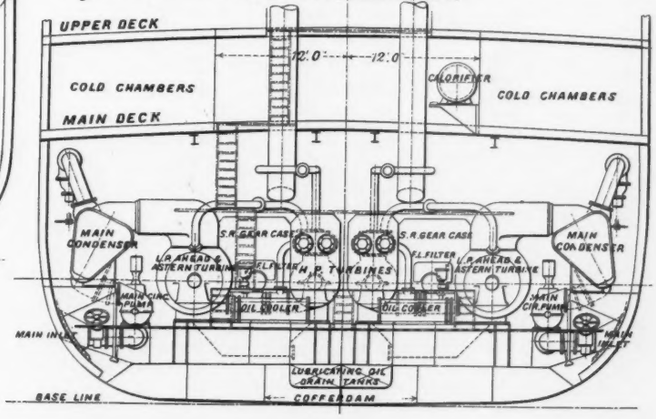


Fig. 19. SECTION AT FRAME 73. LOOKING AFT.



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Two-Page Plate.—GENERAL ARRANGEMENT OF GEARED TURBINE MACHINERY AND BOILERS OF THE STEAMSHIPS "ACONCAGUA" AND "TENO."

ENGINEERING.

FRIDAY, APRIL 20, 1923.

THE LAND DRAINAGE AND UNEMPLOYMENT.

IN the year 1918 the then Board of Agriculture and Fisheries were successful in obtaining an Act amending the Land Drainage Act of 1861 and conferring special powers on the Board (now the Ministry) of Agriculture. It is interesting to examine the powers possessed thereunder by the Ministry of Agriculture and the operation of this amending Act in regard to the interests of landowners generally and to the relief of unemployment in particular.

It is necessary first to examine the general intentions of the Act which confers the existing authority of Level and Sewer Commissioners established prior to 1918 and gives power to the Ministry to curtail or extend the areas under the control of such existing Commissions. An instance of the use of this power conferred by the Act has been the amendments of boundaries between certain of the several Essex Sewer Commissions.

Provision is also made for the creation of new Drainage Boards with functions similar to those possessed by the older Commissions. These new Drainage Boards are constituted partly by elected members and partly by members nominated by existing public authorities in, or affected by, the newly-controlled area. Several new Boards have been created, notably and amongst the more important, the River Ouse Irrigation Board and the Maldon, Wivenhoe and Clacton Drainage Board, the latter controlling some 90 miles of sea and river walls.

These new Drainage Boards have come into being in some cases at the instance of the Ministry of Agriculture, and in some cases as the result of petitions presented to the Ministry by landowners. In the case of an entirely new Drainage Board it is necessary that such a petition should be made by the proprietors of at least one-tenth of the area to be controlled by the proposed new Board. A Drainage Board with the approval of the Ministry of Agriculture, may also take over the responsibility for inland navigation (*i.e.*, control of canals, etc.) where the navigable waterways form part of the recognised drainage system. One of the first effects of the Act was to reawake the sense of responsibility in the case of existing Commissions whose powers had not been exercised to their full extent for many years. The creation of new Drainage Boards sanctioned by the Ministry is steadily proceeding. The ultimate combination of the older Commissions with those already created and to be constituted will be the creation of a continuous line of defence against inundation of low-lying lands by the sea or rivers. Breaches in river banks with the accompanying flooding and destruction of land should occur with less frequency, as the whole of the river and sea walls in this country will be definitely under Commission. Nothing but good can arise from such a policy.

The short title of the Act is to some extent misleading, because although it is true inland areas are principally concerned with surface drainage problems, the Commissions on the coast line are principally concerned with the maintenance of river and sea walls and the sluices passing through them. They are, in fact, more intimately concerned with the question of possible inundation than drainage of surface water, except in so far as the latter depends on the proper maintenance of tidal sluices.

There are many other minor points in the Act which are of importance, but largely deal with the action which the Ministry of Agriculture are permitted to take in cases where Commissioners or Drainage Boards fail to carry out their duties satisfactorily, or where landowners fail to carry out Orders made on their properties by duly established Commissions.

In the case of the older Commissions, which existed before the new Act became law on July 30, 1918, no great changes have occurred in their administration as the members of these Boards are not necessarily resident in the areas concerned. They are nominated for life or until their resignation, and over a period of years have become acquainted with their work. The administrations of these Commissions were, and remain, in the hands of the Clerk to the Commissioners, their Engineer and their Marsh Bailiff, who are, in fact, Government officials. The Treasury has latterly sanctioned certain expenditure through the Ministry of Agriculture on reclamation and sea defence works, with a view to the employment of otherwise unemployed labour. The control and execution of most works of this character has necessarily rested more with the Ministry of Agriculture and private landowners not under Commission, and with new Drainage Boards, than with the older Commissions, by virtue of the fact that the latter control areas, where through continued inspection and maintenance the walls, sluices and waterways have been duly and properly maintained, giving little outlet for expenditure of this character.

The Drainage Boards, with the exception of a minority of "appointed" members, are composed of members having definite land holdings in the areas under Commission, and in that respect the new Drainage Boards differ essentially in their constitution from most of the older Level or Sewer Commissioners.

There were only a few of the new Drainage Boards in operation during the winter of 1921–22, and a great deal of the expenditure under the Treasury grant was, therefore, directly undertaken by private landowners who received a portion of their expenditure on any approved scheme from the Ministry of Agriculture in consideration of the employment of unemployed labour. The result of this has been that, although a certain amount of inspection was undertaken by the technical officers of the Ministry of Agriculture, no definite surveys were undertaken, and the different landowners made up their river embankments to different crest levels and different slopes leading to very chaotic conditions.

In September, 1922, when the unemployment question was becoming acute in this country, a Treasury Grant of over £300,000 was made to the Ministry of Agriculture for the relief of unemployment in the winter 1922–23. This grant had to be expended on works of reclamation, maintenance of river and sea walls, and waterways. The New drainage Boards were invited to submit schemes for the approval of the Ministry, and considerable works were sanctioned under this authority last autumn. The schemes were again confined to works where the bulk of expenditure would go in the payment of labour, and this condition naturally

restricted such schemes to the re-making of clay embankments or construction of new clay dams and the clearing of ditches, the amount to be spent on such materials as piling, stakes, ragstone, pitching, chalk, concrete and timber being severely restricted.

It is of interest to examine how far the 1918 Drainage Act and the Treasury Grants to the Ministry of Agriculture for relieving unemployment in winter have worked out in practice. In the first instance, the restriction on the proportionate expenditure on materials as against the proportionate expenditure on labour have re-acted adversely in the interests of the landowners, and these restrictions are probably not to the best interests of the unemployed themselves. The limits of approximately 20 per cent. on materials and 80 per cent. on labour have definitely excluded certain reclamation schemes of sound character and of some definite national benefit. In one instance, a proposal to short-circuit some 2 miles of sea wall by an embankment across the narrow mouth of a creek was found to be outside the limits imposed by the Ministry of Agriculture, owing to the fact that a short length of timber dam formed an essential part of the scheme, but involved too high a proportion of expenditure on materials. Large areas of land now subjected to regular flooding every winter can be readily reclaimed by the construction of suitable dams and sluices, but the cost of materials, such as gravel, cement, bricks, cast-iron pipes, timber, penstock valves, tidal flaps, &c., is greater than the cost of labour. Indirectly, however, the land so reclaimed would enable landowners to develop their properties, and employ labour which is at present still seeking employment.

The notification of the last Treasury Grant in respect of works to be executed during the present winter (1922–23) reached the Drainage Boards and Sewer Commissioners from the Ministry of Agriculture as late as September last. In this direction it is important to note that, with the somewhat slow moving machinery of the Drainage Boards' organisations, this notification came too late to permit of the preparation of a really efficient programme for the winter undertakings.

The Act makes no provision for covering the expense of necessary preliminary survey work, and the remuneration sanctioned by the Ministry and available for the payment of competent Marsh Bailiffs is not sufficient to provide suitable technical assistance for this class of work.

The new Drainage Boards are also apt to look upon such expenditure as unnecessary. The result, as can be imagined, is the hurried sanction by the Ministry of Agriculture to expenditure on works which are not properly set out and, therefore, to expenditure of doubtful utility. On the other hand, one can well sympathise with these newly-formed bodies in that they generally control agricultural land of a very low rateable value, and they have really no means of raising adequate funds for survey work.

After work is commenced, progress is regularly inspected by capable technical officers of the Ministry of Agriculture and sometimes condemned. As indicated above, this unsatisfactory condition of affairs is entirely due to the absence of any reasonable allowance from public funds to cover the cost of preliminary surveys over areas not previously under Commission.

If unemployment continues to be a serious menace to this country and similar relief is to be granted next winter, it follows that the Drainage Boards should be notified as early as possible, and be called upon to obtain qualified advice and to have the proposed works properly set out with working drawings and estimates and specification. There can then be no doubt that public money will be properly expended, and the Drainage Boards should be allowed to debit the cost of this preliminary work as a first charge against any Government Grant.

Grants such as those now in operation absorb several thousand unemployed over the winter months and, as they are a definite burden on the taxpayer, every precaution should be taken to ensure that all expenditure is to the best national advantage.

It must not be forgotten that the ultimate burden of expenditure under the present arrangement is divided as to 25 per cent. to the landowners and 75 per cent. to the Government. This division of expenditure naturally attracts landowners who embark on schemes which would probably otherwise be left alone. It is, therefore, of paramount importance to consider not only whether the money is being spent in the partial relief of unemployment, but whether even 25 per cent. of such total expenditure when borne by a landowner, represents any permanent gain either to the country as a whole or to the landowner in particular. The present scheme lacks breadth of view by the continued insistence that practically all the grant must be expended on labour. In other words, a clay embankment may be sanctioned likely to be destroyed by the sea in a few years for the want of funds to provide the necessary stone, chalk or concrete revetement to protect the sea and river slopes of the bank, when constructed, the cost of which would certainly bear a higher proportion to the total cost of works than is permissible under the present scheme.

VARIATIONS OF EFFICIENCY IN COTTON WEAVING.

THE report on humidity, temperature and ventilation of weaving sheds recently issued by the Industrial Fatigue Research Board (ENGINEERING, April 6, 1923) dealt with one aspect of an investigation into weaving that the Board first undertook in 1919, and placed under the direction of Mr. S. Wyatt. A further report by Mr. Wyatt, dealing with the main investigations, has now been published (No. 23. "Variations in Efficiency in Cotton Weaving"; H.M. Stationery Office; 3s. net). The purpose of the investigations was to determine the nature and general effect of the factors that influence the efficiency and fatigability of weavers, so as to allow these factors to be enumerated and classified. For the time being no serious attempt has been made to isolate the separate effects of these factors, or to ascertain the practical value of modifications in methods and conditions of work. It is thought that these questions should be left for a later inquiry, which the Board would not feel justified in undertaking in the interest of an individual industry, except with the active co-operation and assistance of the industry itself.

The report now presented is mainly statistical. Regarded mathematically, it does not lead to much positive inference, but what conclusions it suggests are supported by a far larger body of observation than have been usual even in work of much greater pretensions. It was desired to take advantage of the fact that a great deal of weaving consists of the unaltered repetition of the same work, and the first condition of the choice of sheds to be investigated was therefore that they should exhibit this character as fully as the scheme of observation required. Accordingly, after consultation with many employers in various parts of Lancashire some nine sheds were selected, each of which was prepared to keep its looms engaged constantly on the same material for twelve months under as nearly as possible constant conditions of work. Some of these sheds with artificial humidification and some without placed at the Board's disposal an aggregate of 261 ordinary looms, and some artificially humidified sheds an aggregate of 344 automatic looms, each loom fitted with a pick recorder. The recorders of the ordinary looms were read hourly during this period, and of the automatic looms twice a day, making in all over 1,000,000 observations, a large part of the work having been done on a 55½-hour week. Sheds that were able to keep looms employed continuously for so long a period on producing the same material doubtless were above the average of efficiency. This circumstance, however, had the advantage that any defects the investigation might disclose and any modifications of method they might suggest, could be assumed safely, without fear of over-statement, to be applicable to the industry in general.

For the most part the figures presented are those of output, or number of picks done, expressed as percentages of the maximum number of picks the looms would do if they ran continuously. These percentages measured the efficiency of the work; but their significance for the purpose of the report was masked to some extent by the fact that perhaps four-fifths to nine-tenths of the output depended on the machine and not on the worker. With an efficiency of work of 90 per cent., for instance, the machine would be running unassisted for 54 minutes out of the hour, and the worker would be engaged in attending to loom stoppages—which, apart from a weekly cleaning, was her sole task—only for 6 minutes. If, therefore, this 6 minutes increased in a different hour to 6·6, the worker would be taking 10 per cent. longer time, a period quite long enough to be significant in any comparison of the worker's fitness in the two separate hours, but in the record of efficiency of the work represented by a drop of only 1 per cent. Accordingly for some purposes, notably the observation of reductions of output that might be due to fatigue, the expression of efficiency was slightly altered. Instead of the standard on which the percentage was calculated being the maximum possible output of the loom, the time spent by the worker in actual work on the day of the week and in the hour during which she did best was taken as a standard, and the relative inefficiencies of other hours were expressed as percentages of this time, care being taken that the periods compared had the same temperature and humidity.

A number of interesting results were obtained. The efficiency of the looms making plain cloth was high, about 85 per cent. for ordinary looms and 92·2 per cent. for automatics; though owing to the slower speed of the automatic looms the output per loom was rather less than that of the ordinary looms. As against this disadvantage, and presumably also the extra cost of the automatics, must be set the fact that a single worker controls 20 to 24 of the automatics, but only 3 to 4 of the ordinary. Owing to the predominant influence of the mechanical working of the loom, added to the fairly constant atmospheric conditions intentionally maintained in the sheds, the efficiency was very uniform throughout the year, week or day, except for decreases on Saturdays during cleaning up and on Monday mornings, because they are Monday mornings, and in the before-breakfast period where a two-break day was worked, and for increases just before booking-up completed work for weekly piece-wage purposes. Decrease was also noted during short time, and attributed to a natural desire to conserve work when it was scarce. In dry sheds—that is, those without artificial humidification—variations in temperature and humidity seemed to have very little effect on output, but within certain limits increase of either temperature or humidity in those sheds that were artificially humidified was accompanied by increased output, and the relation seemed to be still closer when output was compared with the product of temperature and humidity. Unfortunately no comparison is given of variations in output or of those of the cooling power of the atmosphere, which in the earlier report seemed to have a greater physiological effect on the workers.

Various effects seen in investigations on other industries appear even more clearly here, and the large number of observations in strictly parallel circumstances that are available lend weight to what they concur in suggesting. It was obviously impracticable to reproduce in the report all the observations on which it was based, and the conclusions to be drawn from it must be made on the assumption that results put forward as typical are really so, which there seems no intrinsic reason to doubt. On this assumption an interesting series of observations may be remarked in regard to the course of efficiency during a working week. Taking hour by hour the time spent by the worker in attending to the looms, it began fairly low—about 2 per cent. over the minimum—on Monday morning, fell in the second hour to 1 per cent. above the minimum, and rose in subsequent morning hours to about 3 per cent.; after dinner it began at the minimum—that is, somewhat higher than in the morning—and fell continuously to about 12 per cent., with a slight slackening in the rate of fall about the middle of the afternoon. This shows a rather more regular course than has usually been observed in other industries, but is not very notable otherwise. On the Tuesday the work began with the minimum for the first hour, and thereafter took much the same course as the Monday. On the

Wednesday, Thursday and Friday, however, the time spent in the first hour was fractionally more than the minimum, the Friday being the worst; and on the Thursday and Friday the increase at the end of the day had grown to about 14 per cent. and 15 per cent. respectively. It is suggested very plausibly that the most likely explanation of this course of efficiency is that it is due to fatigue, operating on each day, and not wholly removed by the rest between successive days, so that there was a slight accumulation of fatigue progressing to the end of the week, when the week-end rest seems to have been sufficient to remove it. The trifling excess on Monday morning is attributed to what the psychologists call technically incitement, or when they are speaking in their shirt sleeves getting into swing, the week-end rest having interrupted the rhythm of work. Broadly the report concludes that the time required to attend to loom stoppages is greater in the afternoon than in the morning spells of work, and increases progressively throughout both the day and the week; and though the variations have no great effect on output, they are important as indicating the extent to which fatigue may be present in weaving. It may perhaps be added that they offer an unusually clear example of a daily accumulation of fatigue and of its weekly removal; for, as explained above, the decrease in output means a much greater decrease in the efficiency of the weaver for the time being.

A certain amount of work was done on the extent to which output was affected by the lighting of the sheds, including some photometrical observations, made in duplicate until both observers agreed within 0·05 ft.-candle. No very concrete results emerged, owing apparently to the difficulty of instituting comparisons between sheds whose lighting arrangements were materially different from each other. In one shed, which is noted as being unusually well lit, as good results were found when artificial light was used as in daylight, which seems to support the view that appropriate artificial lighting may replace daylight without loss of efficiency. In other sheds, daylight work seems to have been more efficient than artificial light. In a shed, for example, that worked on a two-break day and thus did a larger part of its work by artificial light, the efficiency of the before-breakfast work was 8·7 per cent. less than that of the after-breakfast morning work in winter, when artificial light had generally to be used, as against a difference of only 1·7 per cent. observed during summer. That this was not due to a slower recovery from the strain of winter temperature while out of the factory seems clear from the fact that a similar difference was found on comparing the efficiencies for afternoons, which in winter, when a large part had to be done by artificial light, was 6·1 per cent. less than that of the after-breakfast morning, while in summer it was actually 1 per cent. more. But though there seems to be no question but that good lighting is accompanied by better output than bad, and that glare and shadows tend to increase the time occupied in attending to stoppages, no exact figures can be given to represent the relation of output to this factor. It must, however, be remembered that exact figures are less the purpose of the report than the identification of the factors, and perhaps of the orders of magnitude of their influence on output.

Some attention was given to the effect of differences in individual ability. That such differences exist and may be very considerable is said to be broadly evident from the fact that of ordinary looms weaving the same kind of cloth one weaver may control five or six and another only two. It is said further to be quite common for a weaver, when given an additional loom, to give it up after a short trial. These facts in themselves do not show conclusively that the differences in question arose wholly from differences in ability, though they are hard to understand unless considerable differences in ability do exist. To throw further light on the matter the results of one shed for a typical summer month were set out separately for each loom and worker, and showed that the efficiency of individual workers, measured by the outputs of the groups of three looms that a worker controlled, varied from 70·2 to 92·6. When account is taken of the large extent to which this output depends on the merely mechanical operation of the loom, and of the fact that all the looms were weaving exactly the same class of cloth, this seems a very wide difference indeed; and having regard to the fact that all the workers are said to have been experienced weavers, employed by the firm for several years previously, it may fairly be held to show, as the report suggests, that some of the workers suffered either from natural unfitness for the work or the use of defective methods. At the same time quite substantial differences in output were observed within the groups of three looms controlled by individual workers, some as high as 7 per cent.; indicating that a part of the inefficiency shown over the whole set of figures was due to mechanical defects in the looms or—seemingly an unlikely alternative—to differences in the yarn. At the same time evidence is given of wide differences in the liability of what apparently was the same yarn to breakage, which seemed to stand in no sort of relation to variations of either temperature or humidity. These may, as the report suggests, have been due to some original irregularity of the cotton or of its treatment at some earlier stage of manufacture, though on the evidence there seems nothing to exclude some mechanical idiosyncracies of individual looms. In either case it seems certainly to be independent of the worker, and to involve a sufficiently important loss of output to be worth further attention. Similar losses are suggested as arising from injudicious speeding of looms. Increase of speed increases output up to a certain point, which is defined as the speed at which an increase in speed entails an increase in breakages that offsets the increase in output. The report instances looms in one shed working on the same material of which the speeds varied over 7 per cent. On the supposition that this variation was merely accidental it showed, as the report suggests, an avoidable loss of output. At the same time it is to be remarked that the evidence quoted does not show whether this variation was in fact accidental, or whether it arose through some looms being recognised as harder on the threads than others, and speeded accordingly.

Though no additional work was undertaken to enable results of the investigation to be applied in practice, some suggestions are made of directions in which they may be of use. The best compromise between the needs of the yarns and of the weaver in respect of temperature and humidity seems to be a dry-bulb temperature of 70 deg. to 75 deg. F., and a relative humidity of 80 per cent. to 85 per cent. The number of breakages, however, would apparently be reduced if the yarn could be exposed to a still higher temperature and humidity, and the report urges the renewal of attempts, hitherto made with unsatisfactory results, to produce a local atmosphere round the loom, giving the yarn a temperature and humidity from which the weaver should be protected. Apart from some such drastic measures, which proposes a difficult though perhaps not impossible problem for the attention of engineers, the chief opening for modification of atmospheric conditions is said to lie in the direction of keeping the summer temperature within reasonable limits or reducing its harmful effects on the weaver. Atomised water and conditioned air have been used in some cases, but such methods could, as it is said, be developed further, together with means for increasing the circulation of air, as suggested in the previous report. An alternative line of inquiry is to try to obtain a substitute for size, the need for high temperature and humidity being attributed to the use of this substance for impregnating yarn.

Of suggestions for further investigation along the same lines perhaps the most natural is that it should be applied to sheds of lower efficiency and engaged on more complicated work and finer yarns, where variations of human ability must be exercising a greater effect than in the sheds and work already considered. In particular it is thought desirable that systematic comparison should be made between the results from dry and "humid" sheds in which the conditions of work are otherwise similar, determining the hourly variations of efficiency and the number and nature of yarn breakages over a period of not less than three months, preferably in the summer, and if possible with determinations of the cheek and body temperatures of the weavers, and in dry sheds of the nature and amount of atmospheric dust. It is hoped also that the conjectures as to the effect of weaving conditions in both dry and humid sheds may be checked by a study of sickness and mortality records, which if made under suitable conditions and with sufficient care, might conclusively verify or correct the conclusions regarding the effect of the work on the health of weavers that seem to follow from the results of efficiency investigations.

At the same time the facts already disclosed seem, it is suggested, to show that efficiency records have a practical importance which as yet the cotton industry has not fully realised, and that the cost of such records in clerical labour should be much more than recouped by the increased knowledge of the existence and causes of inefficiency, and the suggestion of means to remove them, or, at least, to abate their effects. Problems such as the most suitable speed for looms and the best number of looms, especially automatics, to be worked by a single weaver, could be studied in this way with a high prospect of valuable results. Similarly, the report suggests that the wide variations in the performance of different weavers are evidence of the need for vocational selection and manipulative training. It is thought that some scientific system of guidance would reduce the number of persons who are engaged on weaving with less than sufficient natural aptitude for it, and so lay the foundation for an increase in productive efficiency.

The mere selection of the best-fitted persons for admission into the trade is, however, not put forward as a complete solution of the problem. It is held that the logical sequence of such selection is to train the workers in the best methods of work and to make a scientific study of its principles. For this purpose a careful analysis is recommended if the methods employed by the most efficient workers, and the training of recruits in these methods by experienced weavers who are also capable weavers. This is the method applied over thirty years ago by Taylor, and in recent years developed notably by Gilbreth; and, since the Board is not likely to be deluded into the fallacy that there is only one best way of work for workers who anatomically, physiologically and psychologically are made in a great many different ways, it is most satisfactory that it should be urging the importance of using in these industrial inquiries whatever information can be obtained by examining existing industrial practice. Like the suggested investigations into the speed and operation of looms and the quality of yarn, and like countless possible inquiries in the engineering trades, the work cannot be done without the intimate co-operation of scientific technologists who are also skilled craftsmen. Considering the vast interests of the entire community in spending its labour resources to the best advantage, and of individual workers in obtaining the best result from the hours they work with the least discomfort or degradation of their powers, it is to be hoped that the suggestions of this report may be an earnest of such co-operation in no distant future. The community, and in particular the engineering industries, have waited long enough for it.

STEAM WAGON OPERATION.

THE organisation of an efficient system of road transport for goods is a task which many people have found to their cost, to be a good deal more formidable than they had at first anticipated. When a firm undertakes the delivery by road of its own goods, the difficulties are minimised because both the volume and the nature of its traffic are known, and the transport department has fairly constant duties to which it can adjust itself. But when transportation is the whole function of a firm, and orders for the conveyance of goods have to be obtained in the open market against the competition of railways, canals or other transport companies, matters take on a very different aspect. The vehicles are engaged in all sorts of jobs and may be distributed all over the country, while the very existence of the firm owning them depends upon a sufficient margin existing between their gross receipts and their expenses of operation, maintenance and depreciation. Under such circumstances it is evident that the management of a fleet of motor vehicles must be regarded as a serious business, which can

only be conducted successfully by paying due attention to the innumerable details upon which efficiency depends.

Being a comparatively new branch of commercial activity, road transport undertakings are without the accumulation of data and experience which are at the disposal of most businesses. The conditions, moreover, vary enormously both as to the nature of the service to be given, the kind of vehicles used and the state of the roads over which they run. There are, nevertheless, certain rules which govern road transport work in common with businesses of every other kind, and among the most important of these is the keeping of accurate working records. Only by so doing, can a constant check upon operating results be maintained, and waste or inefficiency be brought to notice as soon as it appears. The nature of the records which he had found advisable in his own road transport business were explained by Mr. C. Le M. Gosselin, in a paper read at a meeting of the Institution of Automobile Engineers on the 12th inst. The paper was entitled "The Use and Limitations of the Steam Wagon," but as the limitations of such vehicles are fairly obvious, and, except in so far as they are common to all kinds of road transport vehicles, are largely avoidable by suitable design, the most interesting part of the paper was concerned with the operation of a fleet of steam wagons. The object of Mr. Gosselin's paper was not to compare steam wagons with petrol wagons or even to compare the different types of steam wagon with each other, but rather to bring out the broad lines of management, upon which successful working of a fleet of steam wagons depends.

Mr. Gosselin's arguments were illustrated by examples of his own practice. The garage he recommended was a properly heated building with a suitable floor and a steel roof properly protected against corrosion due to the steam and acid fumes from the vehicles. The roof must be fitted with ventilating funnels which can be pulled down over the wagon chimneys when steam is being raised. Especially important was it that a good water supply should be available near each wagon, both for washing out the boilers and for cleaning the vehicles. Adequate storage accommodation for fuel, oil and spare parts was also important. Coke was best stored in bags, and firewood should be cut into uniform sizes for convenience both in use and for rationing. The oil store should be one of the cleanest and tidiest places about the works, the driver of each vehicle being served out every morning with freshly filled oil cans and lamps before proceeding on his journey. A set of cans and lamps belonged to each vehicle and the sense of proprietorship assisted very greatly in getting the men to look after them. The tarpaulins and sheets for covering the loads were also allocated to their respective wagons, and the proper storage and inspection of coverings was highly essential. Every covering, before being put into store was examined in a special loft and all holes made by falling cinders or otherwise were carefully repaired before the sheet was re-issued.

Speaking from his own experience, the author considered that a steam wagon, when properly looked after, could be kept on the roads for an average of 250 days per annum. This allowed for 52 Sundays, 52 shed days for washing out boilers and general cleaning, and 11 days for special repairs and holidays. The economic limits of a steam-wagon's journey lay between a minimum of 5 miles and a maximum of 35 to 40 miles; outside these limits other means of transport would probably be preferable. As regards fuel consumption, this was of course a matter which depended largely upon the nature of the roads and the loads carried, but on present-day main roads, with a useful load of from 9 to 10 tons, it was not uncommon to get 10 miles per cwt. of gas coke or nearly double that mileage with good Welsh steam coal. Much, however, depended on the driver, and in Mr. Gosselin's own fleet of wagons the monthly average distance run per cwt. of coke varied from 6¾ miles in the case of the worst wagon to 10 miles for the best.

The boilers of steam wagons were still unnecessarily troublesome. An engine would last for two or three years without serious overhaul, and boilers should last for the same time if the best service was to be got out of a wagon. Many boilers, however, were hardly good for twelve months' continuous service, and their total useful life only lay between six and ten years. Experience showed that in the case of the Leyland steam wagons used by the author of the paper, the re-tubing of the boilers was necessary after 18,000 to 20,000 miles working; the engines ran for 25,000 to 30,000 miles without overhauling, chain and sprockets needed renewing after 20,000 to 30,000 miles, rubber tyres for the wagons lasted from 16,000 to 20,000 miles, and for the trailers from 20,000 to 30,000 miles. Many gears had been in use for eight or ten years and were still in excellent condition. In order to keep heavy overhauls from too frequent occurrence, and equally, indeed, to maintain the wagons in safe and efficient state for their daily duties, the drivers are required each night to report on a special sheet all details of their vehicles which require attention. The necessary repairs and adjustments are carried out during the night and the various items on the report sheets have to be initialled by the night-fitter before the wagons are again taken out.

For particulars as to the way in which the records of fuel, oil, &c., are kept we would refer those interested to the paper itself. The exact method of keeping such records is of less importance than that they should be kept in some simple manner which yet will enable the information they contain to be intelligible when required. As regards operating costs, Mr. Gosselin found it impossible to obtain figures from other large users for comparison with his own, but he gives the latter in some detail over a period of six months. These are the more interesting in that they enable comparisons to be made between two fleets, one comprising 89·2 per cent. of steam wagons and the other having only 25 per cent. of these vehicles, the balance being petrol wagons. The first, which we may call the steam fleet, showed total operating costs of 28*d.* per mile, as against 27*d.* in the case of the petrol fleet. The running costs were practically identical, being 20·5*d.* as against 20·1*d.* in the respective cases. Wages and drivers' expenses were 11·6*d.* and 11·0*d.* per mile respectively and fuel cost 3·9*d.* per mile for the steamers against 5·0*d.* per mile in the case of the petrol fleet. Wagon and trailer repairs cost 2·3*d.* per mile for the steam wagons and 0·8*d.* per mile for the other type. The steamers were considerably lighter on tyres than their rivals, the maintenance figures per mile being 0·9*d.* and 1·4*d.* respectively.

In these and other figures of cost given by Mr. Gosselin, the steam wagon hardly appears to great advantage, as compared with the petrol wagon, but it must be remembered that the types of machine compared must be taken into consideration. It is not fair to generalise one way or the other upon the data presented. Moreover, whereas the petrol wagon is probably not far from its possible limit of efficiency, the steam wagon has a long way to go in the matter of improvement. There are several designs of boilers, other than the locomotive type, being developed for these vehicles and great improvements are certainly possible. Moreover, the use of condensing engines, with the consequent availability of pure water for boiler feeding, should effect a very noticeable increase in the life of boilers and a decrease in their maintenance costs. These and other features which are now in course of development are likely to improve the status of the steam wagon from the point of view of operating costs, and in view of the fact that their use renders their owners, and to that extent, the country, independent of imported and foreign-controlled fuel, every advance in their design is a matter for congratulation.

MAGNETIC-DRUM RECORDER FOR RADIO-TELEGRAPHY

WITH the rapid progress made in scientific apparatus in recent times it is perhaps not surprising to find that modern requirements can sometimes be met by the employment of some superseded principle or half-forgotten phenomenon which may be applied in a manner quite different from that in which it was originally intended to be used. Occasionally also an old device is re-invented by someone unaware of the earlier work, and this appears to have been the case with the Johnsen-Rahbek effect, which was fully dealt with in our issue of June 3, 1921, on page 685. This effect, it will be remembered, utilised the varying electrostatic attraction between a rotating cylinder made of a semi-conducting material such as lithographic stone or agate and a conducting band in contact with the cylinder, to operate the diaphragm of a loud-speaking telephone. It appears, however, that a very similar effect was used some forty years previously by Edison in his early work on telephony, and moreover, as was pointed out by a correspondent in our issue of June 10, 1921, on page 724, it was due to the observation of an almost identical phenomenon by Elisha Gray that the attention of that scientist was directed to the subject of telephony.

We are led to refer again to this matter after witnessing an extremely interesting demonstration of the application of what appears to be the magnetic analogue of the Johnsen-Rahbek effect to the operation of relays, syphon recorders and transmitting keys used in high-speed radiotelegraphy. The demonstration was given by Dr. N. W. McLachlan, of the Marconi Company, before the Wireless Section of the Institution of Electrical Engineers, on the 11th instant, after he had read a paper explaining the principles of the apparatus and dealing with its design, construction and development. It is no disparagement of the author's work in this direction, however, to point out, as was done by Mr. A. A. Campbell Swinton in the discussion on the paper, that Prof. A. E. Dolbear had described an application of the same phenomenon in the *Journal of the Franklin Institute* as far back as 1879. Prof. Dolbear used what he referred to as the differences in the sliding movements of a soft-iron armature in contact with movable magnetic poles to set up vibrations in a telephone diaphragm, and although Dr. McLachlan's apparatus is not used for telephony, it will be apparent later that its action depends upon the same principle as that employed by Prof. Dolbear.

The essential part of Dr. McLachlan's apparatus is a cylinder of well annealed Swedish iron, made in two equal cup-shaped parts, which are mounted on a soft-iron spindle so that the bottoms of the cups form the ends of the cylinder, and a narrow annular air gap is left between the rims of the cups, which face each other. The hollow cylinder thus formed is about 1¼ in. in diameter and about the same length. Inside the cylinder and encircling the shaft which passes through its axis is fitted a coil of fine wire, the ends of which are brought out through one end of the cylinder and connected to slip rings mounted on the shaft, so that telegraph signal currents can be passed through the coil from brushes bearing on the slip rings. The shaft carrying the cylinder and slip rings is mounted so as to run very truly in accurate ball bearings, and is driven through a worm gear having a 15 : 1 reduction ratio by a small motor running at a maximum speed of 3,000 r.p.m.; the cylinder thus rotates at speeds up to 200 r.p.m.

Resting on the curved surface of the cylinder, in such a position that it bridges the air gap, is a small segmental shoe of soft iron, and to this shoe is screwed a brass plate, which fits loosely in the air gap and prevents lateral movement. Hooks are formed on both ends of the brass plate, and to each of these hooks a spring is attached so as to exert a pull in a direction tangential to the surface of the cylinder. One end of the plate is also connected to the short arm of a bell-crank lever, which can turn through a small angle in the horizontal plane, its motion being limited by a pair of adjustable stops. The long arm of the lever carries the fine tube of a syphon inker, and the lower end of the tube bears on a moving band of paper, on which a record of the movements of the lever is obtained.

The action of the instrument, when used as a syphon recorder, is as follows: When a telegraph signal current is passed through the coil inside the iron cylinder, the resultant magnetic flux passes through the iron circuit formed by the shaft, and the cylinder walls, and is concentrated in the soft-iron shoe bridging the air gap. The flux causes the shoe to adhere to the cylinder, so that, owing to the rotation of the latter, the shoe is drawn round against the action of one of the tangential springs. The bell-

crank lever connected to the shoe is thereby pulled over on to one of the stops, and, as long as the current continues, the bell-crank lever is held in the same position, so that the pen draws a straight line on one side of the centre line of the moving paper band. When the current in the coil ceases, the shoe is pulled back into its original position by the action of the spring, which brings the bell-crank lever into contact with the other stop, so that the pen draws a line on the other side of the centre line of the paper. In this way the dots, dashes and spaces constituting a message in the Morse code are recorded on the paper in the form of a wavy line, but the lateral movement of the pen is so rapid that, even at 200 words per minute, the corners of the curve are only slightly rounded. The instrument is easily capable of working at this or at even higher speeds, up to 360 words a minute, but it is of course necessary to ensure the rapid growth and decay of the current in the coil by introducing a resistance-shunted condenser into the electrical circuit. Full details of the electrical arrangements are given in the paper for both single-current and double-current working, and although we do not propose to deal further with these, we may mention that, for some purposes, a second coil carrying a polarising current is employed in the cylinder. This coil is supplied with a steady current through two additional slip rings, and to the flux produced by this current that due to the signalling current, flowing in a separate coil, is added or subtracted. The arrangement is extremely sensitive, and will work quite satisfactorily with signalling currents of about half a milli-ampere. The instrument can, in fact, be used directly in a valve-receiving circuit, although, so far, this has only been done, in actual traffic, at speeds up to 100 words per minute. In ordinary working, about 25 ampere turns on the coil in the cylinder are adequate for speeds up to 250 words per minute.

With regard to the actual construction of the instrument, we should perhaps explain that the shoe does not bear directly on the soft-iron cylinder, but on two cast-iron rings, with which the rims of the cups are fitted. The rings, when in position, are turned in a lathe with extreme accuracy, so that, according to the author, they run truly to within 0·0001 in., and the shoe is bedded on to the rings with abrasive material so as to ensure perfect contact over the whole of the surface. The life of the shoe is given as from 3,000 to 5,000 hours in ordinary work. Probably as a result of the extremely good contact obtained, the author has discovered that the attraction between the cylinder and shoe is greatly in excess of what would be predicted from theoretical considerations, although he offered no satisfactory explanation of the phenomenon. Calculation of the attraction by the usual formula $B^2A/8\pi$, where B is the flux density and A is the area of contact, and using a coefficient of friction of 0·6, determined experimentally by ordinary loading, was found to give a pull on the shoe, which, in some cases, was only one fiftieth as great as that measured on an actual recorder. Owing to this circumstance, comparatively large working forces are available, and in practice, the steady pull may be varied between 1 lb. and 4 lb., according to the current flowing and to the state of the surface of the cast-iron rings. Assuming the spring tension to be half the pull on the shoe, the net working force will vary between ½ lb. and 2 lb., and since the mass of the moving parts and the moment of inertia of the bell-crank lever are small, the acceleration of the pen arm is very rapid. For an amplitude of 0·05 in., which is quite sufficient to give an easily readable tape, the time occupied by the lever in travelling from one stop to the other is about 1/700 sec, and it is owing to this rapid movement that the message recorded on the tape is composed practically of a series of rectangles.

When the instrument is required for use as a relay, the lever stops are made in the form of electrical contacts, and it is obviously possible for a radio-telegraphic message to be recorded at a receiving station and simultaneously relayed over a land line by the same instrument. The instrument used for operating a radio-telegraphic transmitting key is exactly similar in principle to that above described, but of rather larger dimensions, and the syphon recorder is, of course, omitted. The magnetising current to the coil is controlled by a Wheatstone tape transmitter, and the shoe, which is connected to the transmitting key, gives a working force of from 50 lb. to 70 lb. The apparatus, we may mention, is now well past the experimental stage, having been employed in practical work on the Chelmsford-Paris service of the Marconi Company, and elsewhere. It is also quite possible that applications for the particular magnetic phenomenon upon which it depends for its action may be found in other branches of engineering work than telegraphy. The author, in fact, suggests in his paper that the principle may be employed in connection with the brakes of motor vehicles; but here again its use has apparently been anticipated, since, in the case of tramway cars, magnetic attraction has been used for many years to increase the adhesion between the brake shoe and the rail. However, the matter is of considerable general interest, and every credit is due to the author and his colleagues for having developed it so successfully for the particular purpose they had in view.

THE INSTITUTION OF MECHANICAL ENGINEERS.

Discussion at Manchester on Reports of Steam Nozzles Research Committee.

THE two reports of the Steam Nozzles Research Committee, an abstract of which, together with a report of the discussion in London, was published in our issue of March 23 last, were discussed by the North-Western Branch of the Institution on Thursday, April 12, at Manchester.

The discussion was opened by Mr. J. P. Chittenden, who congratulated Professor Stoney and the Committee on the results obtained and published in the Reports. The results obtained in the experiments were not only of academic value, but would also be an actual asset to those engaged in turbine construction, and would be the means of improving the efficiency of future designs. The curves published would be a guidance to designers with regard to the selection of both the diameters and the number of stages, and also proved fairly conclusively that the modern tendency of reducing the number of stages and increasing diameters was correct. In the past there had been two schools on this subject—the American school, who favoured a large number of stages of small diameters, and the Continental school, who preferred few stages and large diameters. With regard to the design of the nozzles which were tested, the speaker considered the pitch of the nozzles too small, and if the pitch had been increased higher efficiencies would have been obtained, and there would not have been quite the same difference between curve No. 1 and the remaining curves. The speaker stated that his company were working with nozzles with wider pitches, and would be in a position to check the effect of increasing the pitch. He further suggested that on the same apparatus should be tested the effect of the finish of the surface. This apparatus would provide a most excellent means of seeing the effect of rough surface, as compared with a smooth surface, on the efficiency of the nozzles. Various experimenters had attempted this, but the results obtained were not very satisfactory.

Mr. K. Baumann, having been a member of the Committee since the beginning, in 1912, thought it was hardly appropriate for him to criticise the work that had been done, nor would he be in order in saying many words in praise of the work. Mr. Baumann agreed with the first speaker that the tests were of very great value to turbine industry. Professor Stoney called attention to the big discrepancies which had existed amongst previous results. When the tests were finished those discrepancies would be cleared up, and the turbine designer in future would have some definite basis on which to work. A great deal of development had taken place during the last ten years in the capacity of turbines, but it was also necessary to increase efficiency by improving the details of design.

Mr. Guy stated that those who had had some opportunity of seeing the extreme accuracy, care and patience with which the work was carried out were so satisfied with that work they were bound to accept most of the results which had been presented. The apparatus used had been designed with peculiar ingenuity, largely by Mr. Martin, and was of a really extraordinary sensitiveness. A high degree of sensitiveness was necessary if results of any value at all were to be obtained at the low velocities which had been included in the scope of these experiments. One had only to consider the magnitude of the error which would result in the velocity coefficient from minute friction errors or errors in pressure observations to appreciate the extreme care and skill in experiments which was necessary to keep down errors to the very small limits within which the tests had been kept.

The character of the velocity coefficient curve which was contained in the Report was of peculiar interest, although Mr. Guy ventured to warn anyone from readily falling into the pitfall that Mr. Chittenden had prepared for them. From the results given in the Report, the speaker did not think that it could be taken that the nozzle efficiency necessarily increased as the velocities were increased above a certain velocity, relatively to the velocity coefficient obtained at lower velocities. An examination of the curves in Fig. 1 would bear this out. It would be seen in curve 4 that the coefficiencies round about 1,200 feet per second were as high as those at 1,900 ft. per second, and the coefficients at 400 ft. per second were still higher, but apart from that, in the question of the desirability of adopting a relatively large or small number of stages in a turbine, it should be remembered that nozzle efficiency was only one of the factors, and the range of possible variation was very small compared with the range of variation in the other factors which entered into the balance sheet. With regard to the character of this curve, it was somewhat doubtful whether it could be assumed that its position relative to the velocity base necessarily remained the same throughout the whole range of steam conditions. In a turbine, at the high pressure end, there may be velocities of 1,200 ft. per second and a pressure of up to 200 lb. per square inch, whereas at the exhaust end the pressure may be only 1 lb. per square inch. One knew that velocities varied under those conditions, and wondered whether the point on the velocity efficiency curve was not really a function of the conditions which existed at critical velocities, rather than the function of the absolute magnitude of the velocity. The change-over point from viscous flow to turbulent flow would vary with temperature and pressure conditions. If that were so one might have, for instance, three such curves displaced laterally, one applying to conditions at the high pressure end, one to the middle, and one to the exhaust end. If the Committee could demonstrate by experiment whether such a change took place, a very valuable addition would be made to the knowledge of the subject, even if it were found that no displacement took place.

Mr. Guy mentioned that the British Electrical Industries Research Committee were extremely anxious that this work should be continued, and were willing to help the Committee as they had been doing in the past. Some of the old members of the Institution had often felt that the Institution had existed long enough on the reflected glory of Tower's lubrication experiments, and hoped that in the work of this Committee a new justification would be found for the existence of the Institution.

Mr. T. Petrie drew the attention of the meeting to one or two points in elucidation of the Report. The Report had been drawn up with the idea of stating facts, so that discussion of their nature could take place from data. The point where mixed flow and wholly turbulent flow joined issue, between 600 and 800 ft. per second, was the most difficult point to deal with in the whole run of the experiments. At this point less consistent results were obtained, and in one or two cases it had been difficult to join up mixed flow with wholly turbulent flow. It was evident that something of an unusual nature happened at that point. This was borne out by some analyses done by research students on the work. One showed that between 600 and 800 ft. per second the discharge coefficient became a minimum, and another showed that it was at about that point that a *vena contracta* was formed in the nozzle.

With regard to preliminary curves for efflux angles

given in the first Report, that work had been completed long before the work included in the second Report, and the speaker wished to emphasise the fact that the results did not represent the mean efflux angles of the steam as it left the nozzles, but the efflux angles as the Committee wanted them, some 2½ in. away from the face of the nozzle. The thickness of the plate affected the angle of the steam, the deviation being very much greater with thick plates. Further difficulty on this point was anticipated in the experiments on the 12° nozzles, which vary very much more on a percentage basis. Several speakers had referred to the apparatus used in the tests. It was a novelty and a complete success, the whole apparatus having functioned from the start exactly as it was intended.

Dr. Morley had one or two suggestions to make, although Mr. Guy had covered one, namely, that it seemed desirable that experiments should be repeated, if possible, at various ranges, as it was quite possible that the results obtained at a certain velocity with one pressure would not be the same as those obtained with a different pressure. The speaker also suggested that a further check test should be made with the impact apparatus to see whether any difference would be caused by varying the distance from the nozzle box to the impact plate. With reference to the apparatus, the engineering world was exceedingly indebted to Mr. H. M. Martin, and his name particularly should be associated with the work of the Committee, both for his skill in designing the apparatus and for the great ability he displayed in discussing the theoretical aspects in explanation of the variation in the coefficients obtained. The speaker referred to a paper of his own presented to the Institution in 1916, during the preparation of which he had come into contact with Mr. Martin on this question. He had experienced the same difficulty referred to in the report in the method of determining the velocity by the impact on a plate, and had obtained different results with the plate at different distances from the nozzle, but for a reason wholly different from that already mentioned. He had also got results that apparently indicated a much higher velocity than those obtained by the reaction method. In his paper of 1916, Dr. Morley had attempted to give an explanation of this, which was accepted by Mr. Martin, and was partly responsible for the design of apparatus he adopted. The theory was that the jet issuing from the nozzle was not the only fluid which struck the impact plate. There were set up round about the jet a circulation of air, and the fluid deflected by the plate was not only the original jet, but also some of this circulating air. Mr. Martin's design of the cage was intended to ensure that whatever change of direction took place in the circulating fluid from a motion parallel to the jet to a motion along the plate should be balanced by an effect due to the other changes of direction of the circulating air. For that reason he adopted the cage with a series of rings, forming parallel discs, so that the air had to enter at right angles, and also that the air thus entering was caught upon the top plate before turning and following the direction of the jet. By adopting wire gauze on the plate, the Committee had also endeavoured to ensure that whatever circulation of air and other fluid there was associated with the jet should be at extremely low velocities.

Mr. N. Elce, with regard to the vibration which occurred in the measuring arm, mentioned in the second report, asked whether this was partly due to the flapping movement of the jet. The speaker also asked how long it took the committee to test out a given nozzle in a given setting.

Mr. Konig congratulated the Committee on having eliminated for the first time by their ingenious cage arrangement the discrepancies between impulse and reaction tests. Regarding the shape of the tested nozzles, it might be said that they were so far not of a commercial form, as the extremely small opening of ¼ in. was practically never used. The difficulties of core box, &c., generally required a minimum opening of about 4 in. The actual opening of the tested nozzles of 0·25 in. gave an unusually bad hydraulic depth. This fact, in addition to those mentioned in the second Report, had given rather a low efficiency for the nozzles tested. Regarding the angle of efflux, the measurement of this angle to one-third of a degree must be considered as rather bold, bearing in mind the eddying conditions at the exit of any nozzle.

As to the equation given in the second Report, it should again be borne in mind that when working over the critical pressure ratio, the equations of impulse gave the actual velocities somewhat distant from the nozzle area where the back pressure was reached. The efficiency deduced included in this case the expansion in the clearance space. With regard to the disturbing influence of the flat surface at the end of the nozzle group, mentioned in the report, it might be of interest to know that the English Electric Company had provided in their nozzle instructions that in partial blading the end of a nozzle batch had to be cut back in the same way as had been done by the Committee. This Company had also tapered the exit of the discharge edge of every nozzle (even when convergent) in such a manner that the throat area, and therefore the flare of the nozzle, was practically unaltered. The disadvantage of the flat surface at the discharge edge was thereby overcome. Concerning the mean angle of efflux from the nozzle, it should be remembered that this was not only a function of the pressure ratio, but depended to some extent on the length of the parallel guide of the nozzle.

Mr. J. A. Campbell said that the discovery of "flapping" was most interesting, but it would almost appear that the distance from the edge of the nozzle to the point at which any material change of angle took place was greater than anything worked to in practice. In Tables 1, 2, 3, 4 and 5, giving the results of the tests for velocity coefficient, there were one or two features which were worthy of note. In many cases where two tests or more had been carried out with practically the same initial and final pressure, but with varying superheat, the velocity coefficient obtained with the higher superheat was in most cases lower than that with the lower superheat. This seemed to be rather at variance with the usual beliefs. Mr. Martin's remarks at the London meeting regarding turbulence and *vena contracta* in the nozzles were most interesting, and would seem to explain quite a lot of the peculiar behaviour in steam nozzles. The reasons given for the adoption of superheat for these tests of such a degree as would ensure a condition of superheat at the exit of the nozzle were quite good, but where the final pressures varied considerably in amount, there was a probability that some of the results and conclusions would be very different. This was put forward as a suggestion which might be considered after the present series of tests was completed.

Professor Stoney, in reply to the discussion, stated that he had been engaged in turbine engineering since 1888, when the biggest turbine made was 50 h.p. It had always been his wish to engage in research work which would be useful to the turbine industry, as in this way he could do most towards the advancement and progress of the work.

With regard to Mr. Chittenden's remarks, Professor Stoney stated that as soon as the necessary drawings of the nozzles referred to were received by him, he would be willing to test them. Experiments on the finish of nozzles could also be taken, and it was the intention of the Committee to make tests with various pressures, as suggested by Mr. Guy. With the apparatus used in the tests it would be possible to go to a back pressure of 60 lbs. and initial pressure of anything up to 200 lbs. Professor Stoney agreed with Mr. Guy that probably the curve would shift to the right or to the left according to the steam pressure used. If the limiting velocity was about 2,100 ft. in these tests this was about 38 per cent. above the critical velocity of 1,600 ft., and it was believed that 38 per cent. would be true right through the series. If this was so, it would mean that the rule adopted by steam turbine designers of calculating theoretically and deducting 10 per cent. would be more or less correct. With regard to Mr. Morley's reference to the effect of varying the distance of the plate from the nozzle, this had been tried but was found to have no effect. With regard to vibration, this only occurred when using a spring balance. When this had been done away with and the impulse taken by dead weights, the momentum had been sufficient to eliminate vibration. A test generally took from two to three weeks, although of course the apparatus had to be run for a while to get everything thoroughly warmed up.

NOTES.

NICKEL-CHROMIUM STEELS.

ALTHOUGH the properties and peculiarities of the nickel-chromium steels (Ni 2 to 4 per cent., Cr 0·5 to 1 per cent.) are fairly well known, and are frequently discussed at the meetings of metallurgical societies, the R.D. Report, No. 55, recently issued by the Research Department, Woolwich, in which the results of extensive research into the whole subject are set out, will be of much value. A large part of the information it contains is in tabular form. The work was carried out on specimens taken from various forgings of low and medium carbon nickel-chromium steels, and also on one type containing molybdenum. The report points out that some of the steels dealt with, containing from 1·96 per cent. to 3 per cent. of nickel, and 1·04 to 2·18 per cent. of chromium, showing high tensile test figures both when quickly cooled in water and slowly cooled from the tempering temperature, gave average Izod impact figures in foot-lbs. varying as much as from 47, 45 and 56 for the water-cooled specimens, to 3, 2 and 3 respectively for the slowly cooled ones. Other steels, containing between 1·47 and 2·82 per cent. of nickel, and between 0·24 and 0·34 per cent. of chromium, gave comparatively low tensile test results, but showed very much more uniformity in the Izod impact figures when water-cooled and cooled slowly. The report takes the ratio of the impact figures of the quickly cooled steel to that of the slowly cooled after tempering, and finds, for the former variety of steels, ratios varying in extent from 14·2 up to 22·5, and for the latter class of steels ratios varying only from 1·04 to 1·2, these ratios being taken as a measure for the susceptibility of the steels to temper-brittleness. It will be seen that in this respect the latter class of steels are very much better than the former variety. But the most interesting alloy in the series is the one called steel "K" in the report, in which some of the chromium is replaced by molybdenum (Ni up to 2·84 per cent., Cr 0·63 to 0·85 per cent., and Mo 0·43 to 0·70 per cent.). This gives good and regular tensile test figures, and was found to be the least susceptible to temper-brittleness; in fact, the Izod impact figure obtained from a specimen after cooling from tempering temperature was practically identical with that obtained from a similar specimen quickly cooled, and this steel, according to the report, "appeared to be quite unsusceptible to temper-brittleness." This characteristic feature is so important that it needs no special emphasis, and the Woolwich Research Department is to be congratulated on the work which is dealt with in the report.

OIL PROSPECTING AND TESTING.

One general feature distinguishes oil and gas mining from the older coal and ore mining. Ordinary mines become surrounded by huge waste and tailing heaps which, a source of trouble at the time, sometimes prove valuable when the rich ores are exhausted. The enormous amounts of oil and gas which run to waste in gushers are irretrievably lost, and the oil left in a well, that had to be closed up, is also frequently lost. On the other hand the driller may easily overlook oil layers actually passed through. That makes very cautious and systematic prospecting advisable; but such methods control the "wild-catter" who is afraid of being anticipated in striking a gusher. Hence the large percentage of "dry," i.e., non-productive wells. In the years 1916–17 all the new wells in the States of Alabama, Arkansas, Arizona, Missouri, Utah, and several others were dry, whilst New York and California had only 4 per cent. and 6 per cent. of dry wells, and the average percentage of unproductive wells of those two years, during which 34,222 wells were completed, was 17. Prospecting goes together with testing; the prospector has to explore and identify the

strata in which oil is expected; the tester has to determine the kind and amount of fluid stored within the pores and crevices exposed. They must work in unison with the geologist, and they depend, much, even when a careful log is kept, on the skill and judgment of the driller. Information on "Prospecting and Testing for Oil and Gas" is given by R. E. Collom in Bulletin 201 of the United States Bureau of Mines. The absence of summaries in his compilation may be taken as a sign of the diversity of the methods and tools used, but it is also a drawback, and the reader will not be pleased to find only a few lines on the defects of anticlinal theory without any explanation of the theory. Oil and gas seepages do not necessarily indicate proper places for tapping the earth. For prospecting and testing cable-tool drilling is better than rotary drilling, because the rotary "walls up" the formation with mud, and changes in its formation are not easily recognised; diamond drills do not answer for great depths. As regards testing, no basin can properly be tested for fluid unless fluids from extraneous sources have been shut off, and the appearance of sands and porous rocks may be deceptive. The shut-off may be effected by means of a casing shoe or cement. Many other appliances must be at the disposal of the prospector if he is to be enabled to prevent future waste and heavy expense.

LITERATURE.

A Dictionary of Applied Physics. Edited by Sir RICHARD GLAZEBROOK, K.C.B., D.Sc., F.R.S. In five volumes. Vol. III. *Meteorology, Metrology and Measuring Apparatus.* London: Macmillan and Co., Limited. 1923. [Price 63s. net.]

WITH commendable promptitude the publishers of this work have issued the third volume in which are treated the subjects of meteorology, metrology and measuring apparatus. In preparing for the press a work for which no previous attempt furnished an adequate guide, and one that demanded the co-operation of many authors, engaged for the most part in professional scientific work, it would not be strange, though it would be regretted, if the collection and arrangement of the mass of material extended over such a lengthy period that the entire work on completion failed to exhibit the position of applied physical science at a particular date. Time is of importance, for it would be inconvenient if results were given in later volumes while omitting to follow the course of investigation in the earlier. The perspective would be distorted by want of simultaneity. Such defects are happily prevented by the energy of those engaged in the work of preparation, and if there are noticeable some repetitions that might have been avoided by more careful dovetailing of the articles of the several authors who approach similar subjects by different roads, these can be easily overlooked as due to eagerness to produce the work as early as possible.

Of omissions, it would be premature to speak till the Dictionary is seen in its entirety, but certainly there are some curious surprises in the method of treatment. For instance, one would have expected to have found some reference to photometry under measuring instruments, but he will be disappointed. Doubtless, the subject will be fully treated in the section of Optics in the next volume. With a thoroughly comprehensive index of the whole work such matters are of small importance, except from the point of view of the purchaser. The subdivision into volumes was intended to be effected in such a manner that those interested in a particular branch of physics would find their requirements met in one volume, which could be obtained independently of the remaining portion. How far this object has been attained is unknown, but judged from this volume, only incompletely. Those desiring information of some forms of pyrometer, for example, would not meet with the necessary description among "measuring instruments," while the student of optics would find the theory of the rainbow relegated to meteorology. The remark is made rather in sympathy with, than in criticism of, the editorial management. The elimination of overlapping must be well nigh insuperable, and if rigidly carried out might not prove desirable.

On consulting the list of contributors we regret to find that some are no longer with us. These emissions must unfortunately grow greater with time, but we wish now to express our regret that the late Professor G. C. Knott, distinguished in so many ways and especially for his researches in seismometry, did not live to see the publication of his article on "Earthquakes and Earthquake-Waves" that so well covers the ground won by persevering inquiry, experimental and theoretical. Similarly Mr. C. Simmonds of the Government Laboratory, who interests us by his discussions on Alcoholometry and Saccharometry has not been permitted to give the finishing touches to his work.

The subject of meteorology, one of the main sections of the Dictionary, is treated in its various aspects by no fewer than six authors, and by this division we are presumably profiting by the accumulated experience of those who are familiar with special investigations, though the advantages are not always apparent. We read with respectful attention Sir Napier Shaw, when he writes on the subject of the Thermodynamics of the Atmosphere, but without any disparagement of Capt. Brunt, we feel that the same writer would have been equally illuminating if he had written on the subject of the Physics of the Atmosphere. The advantages of this distribution among a number of authors are not apparent, though we cannot but be grateful to Mr. W. H. Dines for his description of the means of investigating the conditions that obtain in the free atmosphere, and the results that have been gained by the investigations. Mr. Corless's article on meteorological instruments is interesting and instructive, though the scheme is cramped by the removal of the discussion on Barometers to another place and other competent hands; the explanation of other instruments, such as are used in aviation, is removed to a later section. As engineers, we could have wished that Mr. Corless had told us of an anemometer that would give trustworthy records of wind force over considerable areas. Mr. Skinner's contribution on "Humidity" must necessarily overlap some portion of the ground covered by Mr. Corless. No reference is made to the recent and interesting speculations of Professor Lindemann and Mr. Dobson on the possible increase of temperature at great elevations above the surface.

The second section, devoted to metrology and measuring apparatus, will appeal with special force to those engineers who recognise the close relation between physics and engineering and are aware of the assistance which each has given to the other. The interesting sketch by Sir Horace Darwin and Mr. C. C. Mason on the Design of Scientific Instruments may serve as an introduction to the more technical contributions, on Balances, Metres, Gauges, Time-Keepers and other apparatus, by which the fundamental standards of mass, length and time have been determined and made available to all. The authors indicate the requirements that have to be met in every novel design, and insist on the rules and principles that it is necessary to follow. Generally the facts are all known, but their importance needs to be emphasised at times, and especially when it is necessary to decide between the claims of incompatible qualities as sensitiveness and robustness, cheapness and good workmanship. The authors' long experience in the design of new and untried apparatus leads them to the conviction that good workmanship is small compensation for defective design. Excessive care and costliness in manufacture may hide the latent evils for a time, but wear or injury operates more seriously than on a well designed instrument that does not demand the most skilful workmanship and will give accurate results even after wear is perceptible.

If it be asked what advance has been made in accuracy of construction, Mr. J. E. Sears, the Deputy Warden of the Standards is ready with an answer, so far as figures are capable of expressing the degree of accuracy attained. In the fundamental units of mass, it is shown that a comparison of two kilogramme masses can be effected with an error of less than one part in 100,000,000 (10^8). In length, two yard, or metre, line standards, can be compared with an accuracy of one part in 10^7, while determinations of volume and density may have an error of about one part in 10^5. The measurement of time is necessarily on a different footing. Length and mass are essentially attributes of matter. This is not true of time, for time implies an event or some change in the state of the Universe, but inasmuch as its measurement is necessary, we are driven to the use of some standard and in the last resort to comparisons of length. The unit of time is defined by the period of rotation of the earth upon its axis, and to decide how far this rotation meets the demand for uniformity, and how successfully the subdivision of the day has been effected, reference must be had to the article on "Clocks and Time-Keeping," by Professor Sampson of the Royal Observatory, Edinburgh. Regarded as a standard of uniform motion, the period is liable to change, meteoric accretion will alter the mass, contraction of body must tend to acceleration, and tidal friction to retardation, but as all sources of variation are very small, the difference must be still smaller. The quantity and effect of tidal friction are not discussed in the article on Tides, by Mr. F. J. Selby, who limits attention mainly to the methods of prediction, but the point we would make, is that the amount of error introduced into time measurement, is probably of the same order as that which occurs in mechanical standards. More detailed information of the manner in which accuracy has been secured and maintained will be found in the excellent articles, or treatises, contributed by Mr. Edgar Griffiths on Meters, by Mr. W. H. Johnson on Comparators, and Mr. F. H. Rolt on Gauges, while Mr. Vernon Boys in several articles shows how delicacy of manipulation can increase the nicety of measurement. These and many other papers which may be regarded with even greater interest than those to which we have briefly referred must be passed over without mention. Students of physics will, however, need no words of encouragement to induce them to linger over the facts so forcibly presented by acknowledged authorities, and access to the volumes should be provided wherever physics is taught, research encouraged, or science respected.

The Elementary Principles of Lighting and Photometry. By JOHN W. T. WALSH, M.A., M.Sc., A.M.I.E.E. With a foreword by Sir I. E. PETAVEL, K.B.E., F.R.S., D.Sc., and 85 diagrams by F. G. H. LEWIS. London: Methuen and Co., Limited. [Price 10s. 6d. net.]

REMEMBERING that for a large portion of the day, we are dependent on artificial light for work or recreation, it is surprising that more attention has not been devoted to the study of those conditions that will provide the most satisfactory system of illumination. The absence of daylight appears to have been regarded as a necessary evil, for which there was no remedy, and the discomfort of inefficient substitutes was borne uncomplainingly. The extent to which the comfort, the health, the capacity of all workers was effected passed unheeded. The amount or the distribution of light at home or in the workshop, in school or playground, in theatres or museums was scarcely regarded as a serious problem by the engineer or the architect. Till recently, there were no adequate means of measuring either the intensity of light or of the degree of illumination produced. Definitions were vague and the Parliamentary candle was regarded as a phrase to be treated with ridicule. All this has changed with the introduction of varied and more powerful illuminants, and higher standards have been insisted upon. The possibilities of greater comfort and efficiency have been recognised, and technical science has proved itself competent to meet whatever demands necessity might impose, or fashion dictate. The more the public is made to appreciate the resources of science, the more complete and ready will be the response to these demands, and therefore a warm welcome may be extended to this indirect outcome of the National Physical Laboratory, which provides "a brief and simple guide to the solution of the problems most commonly met with in lighting engineering, and gives both an explanation of the faults which past experience has shown it necessary to avoid, and of the means available for the attainment of a satisfactory result in any given case."

In the earlier chapters Mr. Walsh gives a sketch of the physiological phenomena underlying the process of vision, and though many omissions are

necessarily unavoidable and on many points fuller explanation would be welcome, a very useful purpose is fulfilled, if he can bring home to the untrained optically, that though the eye is an organ possessing great adaptability, there are limits that cannot be overstepped with impunity, and that slow deterioration in sensitiveness is the penalty for neglecting obvious precautions. This practically automatic adjustment of the eye to the conditions in which it is placed constitutes one of the greatest defects, in so far as it facilitates the abuse of the power of regulation. Little attention is given to the risks repeatedly taken, and when the nature of the mischief is detected, it is often found that the damage is beyond repair. It is not a question here of the degree of refraction of a pencil of rays incident upon the eye whose amount can be modified by the use of lenses, but the more insidious imperfections induced by inappreciation of the causes that lead to trouble. One of the commonest and one certainly traceable to injudicious lighting is the effect of "glare," or the inability to perceive objects in the neighbourhood of one much more brilliantly illuminated. The dazzle produced by an unscreened motor car head-light is a familiar example. Another unsuspected cause of danger can be traced to the effect of ultra-violet rays in powerful electric lamps when unprotected by glass which is opaque to these rays.

Care is the more necessary because of the popular demand for more and more brilliant illumination, and too much light by inducing eye fatigue can be as injurious as too little, involving undue strain. Hence follows the necessity for determining the just and adequate illumination for different purposes, industrial and domestic, and when accuracy is required the process is not easy. To determine the difference of intensity of two sources of light, within perhaps 4 per cent. of the total light, is a fairly simple problem by well-known methods, but the measurement of surface illumination for practical purposes presents many difficulties, particularly in the interior of a building, artificially illuminated, where the surface whose amount of illumination is sought may receive light from many subsidiary and varying sources, as walls, ceilings and surrounding objects. Artificial illuminants being poor in the shorter wave lengths, do not give a white light, and differences of colour introduces difficulties in comparing the total illumination of two contiguous surfaces that have not yet been completely overcome. Here, we learn, however, from an expert the methods adopted by the National Physical Laboratory, for securing accurate results and the use made of these results in domestic and industrial life.

The author leads us carefully through the problems that confront the lighting engineer, in the home where decorations and furnishing require that every case should be considered upon its merits, if the artistic sense is to be satisfied and efficient methods of lighting are to be adopted. From the home to the office is but a short step, and the conditions do not greatly differ from those of the house, but in the lighting of public buildings of considerable size — churches, halls and theatres — the view is expressed that great improvements could be effected if closer co-operation existed between the architect and the lighting engineer. In the case of kinema lighting, where great contrasts may arise, very stringent rules have been recommended by the Illuminating Engineering Society in order to prevent fatigue, the annoyance of glare, and to increase the safety of the public. The adoption and enforcement of well-considered rules cannot but be to the general advantage. Picture galleries and museums offer somewhat similar problems, though they have to be solved in other ways. The comfort and requirements of the visitors are well thought out, but the same attention has hardly been bestowed on the exhibits themselves, which are known to suffer deterioration from the action of sunlight or of strong artificial illumination. The success attending, and the methods employed to obtain, an artificial light which approximates daylight in colour are well described in an interesting chapter. The gas-filled lamp provided with an absorbing screen of glass or gelatine, the Sheringham reflective process and the Carbon-dioxide Moore Tube, all seem suitable for the lighting of picture galleries, giving to the hues of pigments their proper tone and values.

Schools and workshops deserve and receive very full treatment. Of late much attention has been given to the lighting of these buildings in which perforce pupils and operatives have to pass many hours each day. Considering the immense importance of artificial illumination as a factor in the progress of the country, it is satisfactory to note that much has been done to remove the reproach of poor, or ill-directed illumination. Several countries have found legislative measures necessary, or desirable, to enforce the recognition of scientific principles in lighting, but the action of the British Home Office does not appear to have advanced beyond the stage of recommendations. These have reference to the amount of lighting necessary for safety, rather than to the arrangements best adapted for efficient work. But the advantages of good lighting are so manifest whether in increasing efficiency or in avoiding accidents, that the self-interest of the employer will generally prove a sufficient incentive. Similarly, in shop-front lighting, into which the element of advertisement enters, competition will secure results both effective and artistic. The application of lighting to many purposes is considered at length, and the book will show to those interested what can be effected, and what material is available for working out a successful result. It is impossible to resist the conviction that illuminating practice has not advanced as rapidly as the development of the materials of illumination and the advance of the science of illumination would appear to make possible.

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WHITWORTH SOCIETY.—A circular letter, copy of the rules, and subscription form have been posted to every Whitworth scholar, exhibitioner and prizeman whose present address is known. The preliminary dinner is to take place on Tuesday, September 11 next, at the Shipping, Engineering and Machinery Exhibition, Olympia, London, where the members will be received by the chairman of the Whitworth Society, Dr. F. S. Hele-Shaw, F.R.S., who is also chairman of the Committee of Experts of the Exhibition. Anyone eligible for membership is requested to communicate at once with the Hon. Secretary, Whitworth Society, Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W. 1.

THE STRUCTURE OF EUTECTICS.*

By ALBERT M. PORTEVIN, Member, Paris.

(*Concluded from page* 480.)

Genesis of the Eutectic Structure.—When the eutectic temperature is passed during cooling, the liquid of eutectic composition becomes saturated with the two constituents of the eutectic, and consequently, in the absence of any surfusion, further cooling would bring about the simultaneous crystallisation of these two constituents. Allowing for the fact that surfusion is but very slight with alloys, this slight delay at the commencement of solidification or surfusion is always present to some extent, however small; the amount of such surfusion may be measured in terms of temperature by the interval, $T - t$, between the actual temperature of the superfused liquid t and the temperature T of solidification—otherwise expressed, the liquid-solid equilibrium corresponding to the concentration of the liquid. This is indicated on the equilibrium diagram as the vertical distance between the theoretical point and the actual corresponding liquidus. The amplitude or degree of surfusion is therefore the temperature interval $T - t$. Thus it is possible to retain a liquid of eutectic composition E (Fig. 36) in a condition of complete surfusion F at a temperature t; the degree of surfusion for the two constituents A and B is then $T - t$, since the saturation point of the liquid is E, or the point of intersection of the two branches of the liquidus. If surfusion occurs only in the case of one constituent, A for example, the theoretical point of the liquid at a temperature t is P, along the branch M E P of the liquidus, corresponding to the separation of A; or, in other words, along the saturation curve of the liquid A. In this case the degree of saturation as regards the other constituent B, is shown by the vertical line P R—that is to say, by $t' - t > T - t$. The crystallisation of one of the constituents of the eutectic increases the degree of surfusion of the liquid in relation to the other, and in this way it may be stated that the crystallisation of one constituent of the eutectic determines that of the other; this phenomena being reciprocal, it is possible to conceive an alternate crystallisation first of one and then of the other constituent. It will be noted that the degree of surfusion brought about by the separation of one constituent depends, for the other, on the relative inclination of the two branches M E P and N E Q around the eutectic point. The limit of surfusion or capacity for surfusion of a liquid with regard to a solid A which separates from it is related to the degree of surfusion $T - t$ by two factors, the power of spontaneous crystallisation N_c and the linear speed of crystallisation V_c, both functions of $T - t$ and of the concentration of the liquid, as shown later. In a general way, it is thus possible to conceive three main methods of crystallisation or genesis of the eutectic aggregate. (1) Simultaneous crystallisation; the particles are formed together in the liquid and subsequently develop either at the same velocity or with different velocities (synchronous or asynchronous crystallisation). (2) Successive crystallisation; the particles of one of the constituents are first formed and develop before the other commences to separate and fill the vacant space. There is then a marked lead in the crystallisation of one of the constituents. (3) Alternate crystallisation of first one and then the other constituent. This is the last variety usually dealt with, and tends towards a lamellar structure if the crystals are almost completely developed in two directions (the two principal crystalline axes) or as alternate zones of each constituent, each enveloping the other (one or three principal crystalline axes).

This is represented diagrammatically, after Vogel, Figs. 37 and 38; but the author has not met with this type of structure in practice. It is therefore only necessary to consider the two previous methods of genesis of the eutectic aggregate.

The successive crystallisation of the two constituents brings about the formation of the first two types of structure, in which the first particles to crystallise retain their original forms (crystals or dendrites), more or less changed according to whether the surfusion of the second constituent is prolonged during the first period of solidification. It is therefore evidently possible to consider the one as the constituent deciding or directing the form of the structure, and as the constituent enveloped during solidification. Simultaneous crystallisation of the two constituents with or without alteration of the speed of progression of the phenomenon, appears to be correctly confined to the third structural type. The causes determining which of these processes shall operate will now be considered.

The work of Tammann has shown that two factors operate during crystallisation or solidification:—

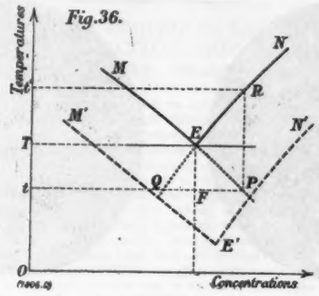
1. The power of spontaneous crystallisation indicated by the number N_c, of centres of crystallisation which are formed per unit of volume during a unit of time.

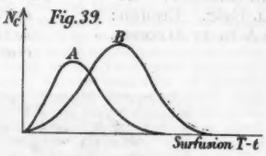
2. The linear speed of crystallisation V_c, or the rate of growth of the crystals from the centres of crystallisation.

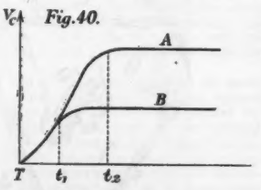
These two factors are a function of the degree of surfusion, and this interdependence is shown graphically by curves of similar form; if the degree of surfusion $T - t$ is plotted as abscissæ, the value of these two factors—at the commencement nil, at the liquid-solid equilibrium temperature T ($t = 0$)—then passes through a maximum, after which it decreases and approaches zero.†

Power of Spontaneous Crystallisation.—By definition, this is the factor on which depends the formation of the centres or axes of crystallisation. If the curves representing the value of N_c for the two constituents A and B of the eutectic, as a function of the degree of surfusion, are clearly different (Fig. 39), it is conceivable that the crystallisation of one of them (A in the figure) will precede that of the other B, according to the positions and respective amplitudes of the maxima of these two curves. Successive crystallisation will occur, and the directing constituent which decides the arrangement of the eutectic structure will be the one in which the power of spontaneous crystallisation N_c increases most rapidly with the degree of surfusion $T - t$, A in the case of the diagram.

When the two N_c curves relative to the two constituents A and B are practically the same, simultaneous crystallisation occurs, and the constituent which directs







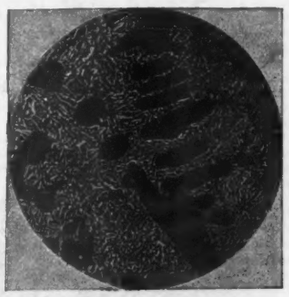


FIG. 41. LOWER SECTION OF A CRUCIBLE CHARGE OF LEAD-ANTIMONY EUTECTIC, SLOWLY SOLIDIFIED. ETCHED: 4 % NITRIC ACID IN ALCOHOL. × 60.

the crystallisation, and consequently regulates or decides the appearance of the eutectic aggregate, is the one possessing the greater speed of crystallisation V_c, as then the extent of crystallisation from the initial centres will overtake that of the other constituent.

Linear Speed of Crystallisation V_c.—This varies with the degree of surfusion in a manner analogous to N_c, but with this difference, that very often (and this should be the case of metals and metallic compounds) the maximum is replaced by an arrest more or less extended on the temperature scale; in other words, there is a temperature area in which the speed of crystallisation is constant and at a maximum (Fig. 40).

The influence of this factor has already been pointed out by Vogel. If it is admitted that, with metals, the curves showing the variation of V_c have practically the same inclination at the commencement, that is to say, with only slight surfusion present, the two constituents A and B of the eutectic will differ only as regards the value of the maximum speed (Fig. 40). Under these conditions, if the amount of surfusion is small between T and t_1 (Fig. 40), A and B crystallise at the same speed, and there occurs simultaneity and synchronism of crystallisation; when the surfusion is greater between t_1 and t_2, one of the two metals will take the lead in the propagation of crystallisation, and will be the directing force in this respect; it is the maximum speed of crystallisation which will determine the eutectic structure. Since, as a general rule with metals, the power of spontaneous crystallisation N_c increases more rapidly with the degree of surfusion than the speed of crystallisation V_c, it is N_c which regulates the genesis of the eutectic aggregate, V_c only intervening in cases of marked surfusion. In short, according to the relative values of N_c and V_c of the two constituents and the amount of surfusion present, it is possible to have simultaneity or "décalage," synchronism or delay in the crystallisation.

Influence of Surfusion.—From the above it is conceivable that if the maximum values of N_c and V_c of the two constituents become inverted, it is possible for the structure of the eutectic to vary with the temperature at which surfusion ceases, as then it will be one or other of the constituents that governs the crystallisation. Moreover, in this connection the previous remarks relative to the reciprocal action of crystallisation of one constituent on the degree of surfusion occurring with the other, and the influence of the inclination of the branches of the liquidus adjacent to the eutectic point, should not be overlooked. The disappearance of surfusion is, as known, dependent on the presence or the introduction of minute crystalline particles and the agitation of the liquid; hence the influence, as shown later, of the pro-eutectic particles and thermal convection currents.

When the maximum N_c occurs in the region of maximum V_c, it is impossible to retain the condition of surfusion during cooling, and this is what occurs with metals and alloys whatever may be the rate of cooling; spontaneous crystallisation always occurs, even in the absence of crystal particles and agitation. Miers and Isaacs have studied these phenomena of surfusion, and have shown that beyond a certain degree, surfusion and the presence of liquid can no longer subsist; these limits of surfusion may be represented round the eutectic point E by two curves E'N' and E'M', meeting at E'; below M'E'N' the liquid state can no longer exist. It will be understood that the composition of the eutectic at the point E in the complete absence of surfusion may be entirely different to the eutectic composition at the point E' when surfusion of both constituents of the eutectic has occurred. This explains the variations, mentioned later, in the mean composition of the eutectic aggregate, according to the nature of the pre-existent pro-eutectic constituent and the rate of cooling.

Surfusion may be produced in one constituent of the eutectic and not in the other, in such a manner that various abnormal eutectic structures are obtained as already observed, during the examination of certain binary alloys, such as gold-nickel (Levin), Cu-Cu_2O (Giraud), Cu_2Mg-$CuMg_2$ (Sahmen). Everything occurs as if there had been primary pro-eutectic solidification of one of the constituents A or B, the structural appearance is modified and the eutectic structure partially or entirely disappears. When solidification occurs by simultaneous deposition of A and B, the aggregate which forms the ground mass no longer possesses the normal concentration, hence the error in the microscopical estimation of the composition. It may be said that, at the time of eutectic crystallisation, owing to the possible phenomena of surfusion, the theoretical point for the liquid may be displaced within the interior of the quadrilateral formed by the curves E M, E N, E'M', E'N', and to follow any path.

From these phenomena it is possible to approximate to the double liquation of the eutectic constituents in the case of slow solidification from a eutectic mixture of which the constituents possess considerable differences in density; for example, this has been verified in the case of the very slow cooling of the lead-antimony eutectic (87 per cent. lead to 13 per cent. antimony); in the lower part of the casting excess lead dendrites are to be observed (Fig. 41), in the upper section crystals of antimony (Fig. 42), and in the middle section the structure of the pure eutectic (Fig. 25, Plate XXXI, *ante*). After rapid cooling of this alloy (chill-cast), the phenomenon previously mentioned is observed—separation in excess of the eutectic composition of the lead and the co-existing antimony, with a ground mass of eutectic aggregate (Fig. 43).

In the case of very slow cooling surfusion is improbable, and crystallisation commences at temperatures approximating to the true eutectic temperature from a number of extremely small centres of crystallisation N_c. These widely distributed centres of crystallisation develop independently of one another; there is no governing or directing constituent, and it would naturally lead to the grained structure of Type IV. Boecke interprets the structure of the deeper minerals in this manner, and explains the absence, in the latter, of the eutectic structures analogous to those met with in metallic alloys; it is probable, he adds, that the two most frequent types of rocks (acid-granite and gabbro-basaltic-basic) possess approximately eutectic compositions, and were in all probability the eutectic portions of enormous magmas which have been forced to the surface of the earth by tectonic forces.

Influence of the Pro-Eutectic Constituent.—From what has already been stated regarding the role taken by surfusion and the influence of crystalline particles, it is conceivable that, in the non-eutectic or hyper- or hypo-eutectic alloys, the presence of pro-eutectic crystals tends to prevent the surfusion of the constituent in question, thus operating on the morphology of the structure, and the composition of the eutectic aggregate. This influence, as will be shown, may manifest itself in three directions:—

1. Composition of the aggregate.
2. Form of the structural particles of the aggregate.
3. Orientation and distribution of these structural particles.

1. *Composition of the Eutectic Aggregate.*—Consider a series of alloys of two metals in which the two eutectic

* Paper read before the Institute of Metals, March 7, 1923. Translated by Leonard Taverner, A.R.S.M., D.I.C., Member.

† It is impossible to give, in this case, a numerical or graphical comparison of these two values, as certain writers have attempted, as they are not of similar character and also have not the same physical measurements.

constituents A and B differ greatly in their tendency to surfuse, and therefore, as already indicated, have very different N_c curves; for example, the constituent A may possess a considerable tendency to surfusion, whereas constituent B does not exhibit this property in at all the same degree.

With alloys containing the constituent A as primary or pro-eutectic particles, these particles on passing through the eutectic temperature prevent the surfusion of A and, since the constituent B is not subject to surfusion, the composition of the eutectic aggregate will be normal. On the other hand, with alloys containing pro-eutectic B, on passing through the eutectic temperature, there will occur a deposition of eutectic B, as in the previous instance, but the crystallisation of A being unaided by the presence of crystalline particles, the liquid cementite plates tends to produce analogous variations in the outline of the eutectic colonies which enclose the plates.

Very frequently the structural particles of the pro-eutectic constituent are surrounded at their point of contact with the eutectic by an envelope of the other constituent; the pro-eutectic crystals tend to cause the deposition of crystals of similar composition from the eutectic liquid, and this process continuing the liquid becomes impoverished in this constituent; the concentration and surfusion of the other constituent is thereby increased, and there follows a deposition of an envelope of this constituent. Moreover, it may be stated that the limits of one constituent can only be marked or indicated by the other constituent and not by the same constituent.

3. *Form or Shape of the Structural Particles of the Eutectic.*—As already stated, Desch has given several examples of the influence of the nature of the pro-eutectic constituent on the form of the structural particles of the eutectic in the case of the copper-antimony alloys. It happens in this instance that, contrary to Vogel's hypothesis, the pro-eutectic particles exert a greater influence upon the eutectic composition than upon the structure.

Influence of Currents in the Liquid and the Rate of Cooling.—The liquid currents may influence the eutectic structure, either mechanically by dividing and dragging away the minute crystals that are formed, or upon the faces of the crystals by facilitating homogeneity of the liquid and diffusion. These currents occur in the liquid owing to differences of temperature (convection currents), of density (diffusion currents), of contraction of solidification (contraction currents); the flowed appearance of the cobalt-antimony eutectic (Fig. 6, Plate XXX, *ante*), is due to the last type of current. The influence exerted by such currents explains the marked growth of crystals along the heat flow-lines—that is to say, along the orthogonal paths of the isothermal surfaces during cooling. Again, with chill-cast alloys the distribution and elongation of structural particles of the eutectic normal to the faces is frequently found (see Vogel, tin-cadmium eutectic). This is a general phenomenon which is not deserving of great attention. But, on the other hand, it is known that cellular vortices, examined by Bénard, Dauzère, &c., exist in the liquid and tend to form a true cellular structure which should bear a direct relation, at least as regards position, to the eutectic colonies previously described.

The rate of cooling affects not only the shape and orientation of the particles, as shown later, but also the degree of fineness and composition of the eutectic aggregate. This effect on the composition has been previously explained in connection with the effects produced by surfusion; it results in causing the appearance of pro-eutectic particles during the rapid cooling of pure eutectic alloys which under slow cooling conditions consist entirely of eutectic; the bismuth-tin eutectic (Figs. 44 and 45) serves as an example of this type. The effect on the size of the particles of the aggregate may also be noted in that instance, but is even more marked when comparing Figs. 24 and 46 of the cadmium-tin eutectic, Figs. 47 and 48 of the aluminium-silicon, and Figs. 23 and 49 of the aluminium-zinc eutectic photographed under the same magnification. Finally, rapid cooling in chills has caused, in certain instances, a special distribution of very finely oriented particles or needles suggesting a "martensitic" structure on the micrographic section: tin-zinc eutectic, Fig. 50, as compared with Fig. 27 (Plate XXXI, *ante*).

Influence of Surface Tension.—The rounded forms, a type of structural particle very frequently met with in eutectics, as already described (see eutectics cadmium-zinc, Fig. 18; cadmium-tin, Fig. 24; copper-cuprous oxide, Fig. 21; antimony-$SbCu_2$, Fig. 31), are evidence

FIG. 42. UPPER SECTION OF A CRUCIBLE CHARGE OF LEAD ANTIMONY-EUTECTIC, SLOWLY SOLIDIFIED. ETCHED: 4 % NITRIC ACID IN ALCOHOL. × 72.

FIG. 43. LEAD-ANTIMONY EUTECTIC, CHILL CAST. ETCHED: 4 % NITRIC ACID IN ALCOHOL. × 165.

FIG. 44. BISMUTH-TIN EUTECTIC, SLOWLY SOLIDIFIED. ETCHED: ACID FERRIC CHLORIDE IN ALCOHOL. × 165.

FIG. 45. BISMUTH-TIN EUTECTIC, CHILL CAST. ETCHED: ACID FERRIC CHLORIDE IN ALCOHOL. × 165.

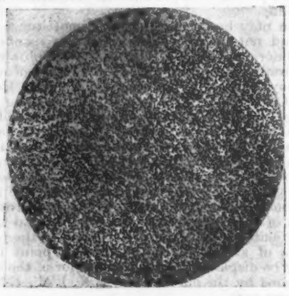


FIG. 46. CADMIUM-TIN EUTECTIC, CHILL CAST. × 165.

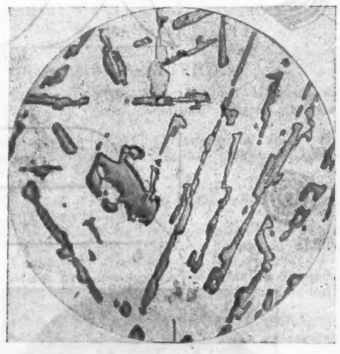


FIG. 47. ALUMINIUM-SILICON EUTECTIC, SLOWLY SOLIDIFIED. × 165.

FIG. 48. ALUMINIUM-SILICON EUTECTIC, CHILL CAST. × 165.

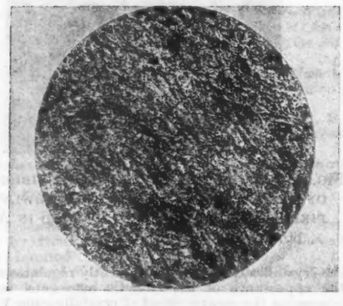


FIG. 49. ALUMINIUM-ZINC EUTECTIC, CHILL CAST. × 165.

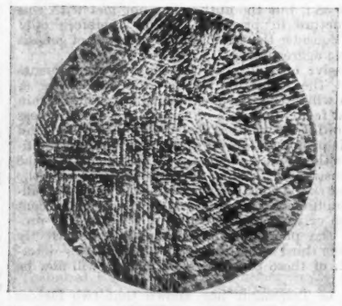


FIG. 50. TIN-ZINC EUTECTIC, CHILL CAST. × 50.

will remain in the surfused condition. The constituent B will continue to crystallise under pro-eutectic conditions in such a manner that the eutectic composition of the liquid will be displaced in respect to this constituent. The eutectic liquid should contain more of the primary B constituent which has been deposited, and therefore the properties of the eutectic aggregate will differ according to whether the alloy contains A or B in the pro-eutectic condition. Microscopical examination will show that the composition of the eutectic does not correspond with the intersection of the two branches of the liquidus as drawn; it will be richer in that constituent possessing the greater tendency to surfusion. An example has been mentioned by Guertler in the tin-cadmium series, where the tin is subject to surfusion but not the cadmium; thermal analysis indicates the eutectic as containing 64·7 per cent. tin, microscopical examination 66·7 per cent. tin—that is to say, microscopical examination gives a result 2 per cent. richer in tin. Roberts-Austen has made analogous observations for the lead-tin alloys.

Finally, in alloys containing but little eutectic, that is, with compositions approaching those of the pure constituents, the true eutectic structure may entirely disappear, and the only indication will be fine particles of the lesser constituent distributed throughout the ground mass of the other constituent forming the major part of the alloy.

2. *Orientation and Distribution of the Structural Particles.*—It is recognised that existing crystals may exercise a controlling influence upon the crystalline particles which may be formed from a liquid phase, and this not only when the latter are of the same kind as the initial crystal, but even when they are of an entirely different constitution. This fact is well known by crystallographers and mineralogists, nature exhibiting numerous examples of oriented arrangement of crystals of different kinds. The hyper-eutectic white irons, as already mentioned, indicate very clearly the directing influence of the cementite plates on the elongated crystals of eutectic cementite (see Fig. 33, page 479, *ante*); additional examples have been mentioned in the case of the ternary alloys of lead, tin and antimony, the orientation of the binary eutectic around the cubic or pseudo-cubic primary crystals being remarkable, giving a covering or cubic envelope. In a contribution relative to the white iron eutectic, Benedicks has shown that the outline of the

of the effect of surface tension in the same way that the curved contours of the dendrites illustrate this effect with pro-eutectic constituents. It is even possible to deduce that the constituent appearing in the pro-eutectic form with plane faces or acute angles will occur in the same alloy in the eutectic form as particles with incurved surfaces and rounded angles (*e.g.*, copper-antimony, iron-cementite). In certain instances, the division of the filaments or plates of the eutectic into rounded globular particles will also be observed (*e.g.*, Fig. 16, cadmium-tin eutectic). Particles with clearly defined angles are an exception in eutectic aggregates and are only found with definite compounds, the metalloids (such as silicon in the silicon-aluminium eutectic, Fig. 47), or with metals of low surface tension such as antimony and bismuth.

F. L. Brady, in a recent and important memoir on eutectic structure,* has quite rightly directed attention to the influence of surface tension, and has even attempted to make this a basis of classification of eutectic structure resembling a purely morphological classification having no bearing on the other physical properties. This would be completely justified if it were not for the fact that, firstly, the information is not complete as to the exact numerical value and variation in the surface tension of the various constituents (pure metals, definite compounds, and solid solutions) separating from alloys during cooling; and secondly, that the surface tension is not the sole factor governing or determining the eutectic structure. That this is the case is shown by the fact that with certain factors (rate of crystallisation, cohesion, viscosity, &c.) there are practically no numerical data nor definite information as to the effects produced as a function of the temperature; the multiplicity of variables co-operating in determining the structure is moreover abundantly shown by the numerous forms of the same eutectic according to the conditions of its preparation. The information previously given results from experimental observations and, in the present case, the morphological images which have enabled the observations to be made and decide the correct lines of the research.

The author was unaware of Mr. Brady's work on this subject until after the preparation of this paper, and, not wishing to enlarge and modify the present communication, the reader is recommended to consult Mr. Brady's paper for all further data relative to surface tension as a factor in eutectic structure.

Relation between the Structure and the Properties of Eutectics.—In general, the variations in structure of a complex aggregate such as a eutectic produce definite effects in the properties; but the question can only be considered in a general manner in the present instance and will be more fully dealt with later; for the present only general indications as to the hardness of eutectic aggregates can be given. The hardness of eutectics may vary according to the fineness, the shape and the distribution of the eutectic particles. The effects of the shape and distribution of the structural particles of a eutectic on the mechanical properties will not be considered in the present instance, only the size of the particles being taken into account. The hardness increases with the fineness of the structure, that is, with the lessening in size of the particles of the mixture, but the increase in hardness only occurs (and this is also true of the chemically homogeneous aggregates) when the particles are below certain definite dimensions; again, the changes in hardness that have been measured for a large number of eutectic alloys are sometimes negligible and sometimes of considerable value. The influence of the fineness of structure is further complicated in some instances by the formation of pro-eutectic particles during rapid cooling, as previously described.

In the following table are given some hardness figures obtained with a 5-mm. ball and a load of 100 kg., the eutectics being cooled very slowly from the liquid state and the other series chill cast:—

Eutectic.	Diameter of the Impression in Millimetres. Slowly Cooled.	Chill Cast.
Lead-tin	2·37	2·10
Lead-cadmium ...	2·90	2·51
Bismuth-tin ...	2·67	2·24
Lead-antimony ...	2·85	2·42
Bismuth-cadmium...	2·65	2·35
Lead-bismuth ...	2·87	2·84
Aluminium-zinc ...	1·30	1·12

This is an effect of structural temper from the liquid state,† and is particularly well marked with the aluminium-silicon eutectic, for which the following figures have been obtained:—

Very slowly cooled, (Fig. 46)	32
Chill-cast, (Fig. 47)	63

This is the alloy known industrially as alphax or silumin‡; the properties are explained by a structural temper bringing about a variation in the fineness of the eutectic aggregate, and the alternative phenomena of surfusion with the abnormal structures previously indicated, due to the influence of the rate of cooling and the viscosity in the liquid state.

It is to the structural fineness of the eutectic aggregate that is due the non-linear variation of the hardness as a function of the concentration in a series of alloys formed of a mixture of the same two constituents with the formation of a eutectic; the latter corresponds to the maximum hardness according to the linear rule. Slowing the rate of cooling in such a manner as to increase the size of the eutectic particles, the linear law is re-established. These phenomena of structural temper and coalescence of the eutectic particles present considerable interest in certain instances from the point of view of the mechanical properties of the alloys and their industrial utilisation.

In conclusion, it may be mentioned that even so simple a structure as that of a simple binary eutectic will supply sufficient data for considerable study and conjecture, and therefore that great care should be exercised in the description and explanation of the effects of structural variations in alloys, especially in the cases of the many more complicated instances to be investigated.

It will be observed that the eutectoids, such as pearlite, which occupy such an important position in industrial alloys, have not been dealt with in the present instance.

* F. L. Brady, "The Structure of Eutectics," Journal of the Institute of Metals, 1922, vol. xxviii, page 369.

† See A. Portevin, *Congrès Métallurgique de Liège*, July, 1922.

‡ For the mechanical properties of this alloy, see Czochralski, *Zeitschrift für Metallkunde*, 1922, and Guillet, *Revue de Metallurgie*, 1922, vol. xix, page 303.

MODEL SCREW PROPELLER EXPERIMENTS WITH MERCANTILE SHIP FORMS.*

By G. S. BAKER, O.B.E., Member of Council, and W. C. S. WIGLEY, M.A.

1. THE paper is intended to give an account of the experimental research work carried out so far in connection with screw propellers at the Froude Tank. The work has been in progress for the past two years, and to some extent is following definite lines. It was intended to limit the research work in the first place to the study of wake and hull efficiency, and the apparatus was completed only to the extent necessary for such work. But it soon became apparent with the rather full-ended ships common in the merchant service, that the big wake fractions and high hull efficiencies which we were getting, especially at light draught, were associated with assumptions which might not be true for this type, and if accepted as they stood might lead to serious error. Something more than this was therefore required, as it appeared that the actual efficiency of the propeller behind the ship might vary with ship condition, *i.e.*, that the relative rotative efficiency could not be assumed as unity. Ship trial results coming to the Tank were supporting this general conclusion, as the reduction of effective horse-power at ballast draught compared with deep draught in the model, was not nearly so apparent in the ship, and this obviously needed some explanation which might be found in the screw efficiency. The design of apparatus for measuring the torque in the propeller driving shaft was therefore put in hand, and after some modification successful apparatus for measuring this torque has been installed on two shafts. This explains the reason why torques are not given with the majority of the work.

2. For some time the work done consisted in more or less normal testing of propellers, single or twin, behind firms' models, modifications of conditions specified by the firm being afterwards carried out for our general information. These tests showed that for single-screw work it was necessary to have the model propellers similar to the firm's propellers as regards general characteristics, such as rake and throw-back, as in some cases these appeared to have a noticeable effect on the result. The propellers mentioned in the following work are therefore of normal design except as regards the boss. Our first propellers were made with a rather small boss, which led to difficulties in casting. This has recently been abandoned in favour of one about normal size. The mode of carrying out such experiments has been detailed on previous occasions before the Institution by Froude and Luke, and no departures from the methods given have been made except in minute detail.

3. Before passing to the actual experiments, it should be stated that the work is being co-ordinated with the analysis of steam trial data as far as this is possible, and our thanks are due to various firms for their assistance, and in particular to Mr. R. Williamson of Messrs. R. Williamson and Son, for permission to publish certain model data given in this paper. The experiments in waves were made with the wave-making apparatus designed and made in connection with certain war work, and through the good services of Sir Eustace d'Eyncourt, presented to the Laboratory by the Lords Commissioners of the Admiralty.

4. *Effect of Immersion of Screw on Thrust and Efficiency.*—A systematic set of experiments has been carried out on seven screws of different normal types, for the purpose of determining the effect of immersion on thrust, and in one case on efficiency. The particulars of these screws are given in Table I.:—

TABLE I.—*Model Screw Propeller Particulars.*

Tank Identification Letter and Number.	Diameter in Inches.	Face Pitch Ratio.	Disc Area Ratio.	Rake Aft at Tip in Inches.
Kb	6·09	—	0·475	Nil
Gb	6·00	0·82	0·475	0·61
IIa	6·00	1·54	0·400	Nil
F2	9·75	1·06	0·466	0·86
17a	8·00	1·14	0·400	Nil
H2	9·85	1·27	0·496	2·10
Q	9·75	1·26	0·466	0·8

The first three screws, Kb, Gb, IIa, were tested at a speed of advance of 515 ft. per minute; the other four, F2, 17a, H2 and Q, at a speed of 200 ft. per minute. All the seven screws were run at immersion to centre of from 1·5 in. to 9 in. The first three would each represent one of a set of 12-ft. diameter twin or quadruple screws on a scale of 1/24 at a speed of about 25 knots. The immersions of the centre of the screw would then have been varied from 3 ft. to 18 ft. The screws F2 and H2 would represent 19 ft. 6 in. diameter single screws on a scale of 1/24 and at a speed of about 10 knots, and on the same scale, the screw 17a would have a diameter of 16 ft., and the immersion would vary from 3 ft. to 18 ft. as for the other screws. At each immersion the propeller was run through a series of slips from zero to about 50 per cent., unless the limit of thrust of the measuring apparatus was reached before this figure, as was the case with the larger screws at deep immersion.

5. *Screw Experiment Results.*—The effect of immersion on the thrust at given slip varied in much the same way with all the screws. Fig. 1 illustrates the results obtained. This shows the thrust coefficients at a number of slips plotted to a base of immersion in terms of diameter. The thrust coefficient is the value of

$$\frac{T}{D^2 V^2} \times \frac{p}{p+21} \times \frac{(1-s)^2}{1{\cdot}02\,s\,(1-0{\cdot}08\,s)}$$

i.e., is the "B" value as used in Froude's methodical screw experiment results.

It is found that at working slips from 30 per cent. to 40 per cent., the thrust developed by the screw begins to fall off as soon as the centre of the screw is immersed a distance less than 0·6 of the diameter, that is, as soon as the thickness of the layer of water over the tips of the screw is less than one-tenth of the screw's diameter. The thrust then decreases with increasing rapidity as the screw is raised, always at a greater rate than does the immersed area. Thus, when there is one-tenth of the screw's diameter projecting above the surface, *i.e.*, the immersion to centre is 0·4 of the diameter, although the loss of area is only 5·5 per cent., the loss in thrusting power is as shown in Table II.

TABLE II.—*Percentage Loss of Thrust at Immersion 0·4 of Diameter at Slips of*

Screw.	35 per Cent.	40 per Cent.	50 per Cent.
Kb	25	37	—
Gb	26	28	44
IIa	32	56	73
F2	16	25	30
17a	22	28	28
H2	22	24	26
Q	24	30	46

The practical effect and application of these results to full-sized screws is discussed in sections 17 and 21 (*c* and *d*).

6. The effect of immersion on efficiency in open water has been measured on one screw, IIa. When the thrust decreases, the torque required to turn the screw also decreases in very much the same manner, so that despite the fairly large variation of thrust the change in efficiency at any definite nominal slip is small, being of the order of 5 per cent. A curve of efficiency for a slip of 28 per cent. for screw IIa is given in Fig. 1 to show the general character of the change.

7. It was not clear from these results whether the variations in thrust and efficiency were due to the surface as a mere boundary, or to it being a free surface with a fluid of very different density on its other side. Propellers have therefore been run under different conditions to determine the effect of a rigid boundary in proximity to the screw. In the first experiment these were an ordinary pair of twin screws: Diameter, 7·07 in.; face pitch, 8·46 in.; disc area ratio, 0·4. These were tested for thrust and torque at a speed of 215 ft. per minute at an immersion to centre of 1·2 diameters. Each of these screws may be regarded as bounded on one side by a fore and aft plane, midway between centres, and any reduction of spread is then equivalent to bringing the screw nearer to the boundary surface. The spread from centre to centre was varied from 1·49 to 1·1 diameters. This change had no perceptible effect upon either thrust or torque at any slip up to 45 per cent., the limit of the tests.

The second test was made with a screw over a rigid false bottom erected in the tank, with its surface 11·75 in. below the free water surface. This bottom extended for 120 ft. along the tank, so that a propeller could be tested for about 120 ft. in deep water, and then 120 ft. in the shallow water in one experimental run. The screw used was 9·75 in. in diameter, 12·25 in. face pitch, the immersion being adjusted to give a clearance of $\frac{1}{10}$ diameter between tip of screw and solid bottom. The speed of the experiments was 200 ft. per minute. There was no detectable difference between the records of thrust and torque in the deep and very shallow water.

8. These experiments show that the thrust and efficiency are unaffected by a single flat boundary surface until the blades make contact with it. Moreover, if any plane be drawn through the axis of a well-buried propeller, the action of the screw would remain the same as it was without this plane. The conditions are then equivalent to a screw with its centre at a solid boundary surface, and this boundary is not influencing the motion. Accepting the conclusion that the water surface as a mere boundary does not affect the working of the screw, the variation of thrust obtained must be due to the freedom of this surface or to the presence of the air above the surface. The freedom of the surface admits of wave motion and of possible cross-flow at the surface due to want of balance of pressure. No measurements of wave motion set up have been made. But since any change of this kind would affect the efficiency to a large extent (and efficiency is not very seriously affected in fact), and since there is a critical speed for the wave-making set up by a travelling submerged point of pressure, and no such critical speed has so far shown itself in the

* Paper read before the Institution of Naval Architects, March 22, 1923.

work, there is no reason for believing that change of wave motion is the cause of the surface effect.

9. In open water, even with the tips of the blades a little out of water, there is practically no cross-flow as the water passes through the propeller, except in two regions. As the blades emerge, water is thrown off in a more or less tangential fashion in the direction of rotation, breaking up into spray. As the blades enter the water, some of the surface water is taken down with the blade, and it is not possible to observe whether air goes with it. This necessarily involves a demand for more water at the surface on the down-going side. With high thrusts this is not forthcoming, a vortex forms, air in large quantities enters the propeller, and the thrust at once drops. The vortex is only produced by the conditions set up in the demand for water to meet the high thrust, and the vortex therefore ceases with the thrust. This is repeated more or less continuously. Even with a screw well buried behind a full-ended ship, something of this sort takes place. The thrust is high at the surface where the water supply is poor. The blades moving across the stern take their supply from the good water on the uprising side, and this moves to the down-moving side of the propeller disc. The free water at the top flows across the stern in the opposite direction to the movement of the propeller blades a few feet below, and in some cases a more or less permanent vortex forms just in front of the propeller disc, on the left-hand side of the stern for clockwise motion of the propeller. It is the presence of the air, and its mixture with the water in contact with the blades, which is believed to account for the large variation of thrust experienced in the model screws. The effect of this conclusion on the applicability of such results to the ship is dealt with in Sections 17 and 21 (*d*).

10. *Experiments in Waves.*—In connection with these varying immersion tests, some experiments have been made with a propeller advancing through waves. The propeller used in the experiments was 17a of Table I. Two immersions of propeller centre were tried, 0·69 and 0·55 diameter in still water, the speeds of advance being 428 ft. and 217 ft. per minute at the deeper immersion, and 217 ft. per minute only at the lighter immersion. The waves varied from 3·2 in. to 6 in. (0·4 to 0·75 diameter) in height from crest to hollow, and from 1·57 seconds to 1·75 seconds in period. The screw was run both advancing into and being overtaken by the waves. With the screw just breaking through the surface at about every other wave hollow, when meeting waves at 217 ft. per minute, the screw gave nearly the same thrust as in smooth water with approximately the same torque, up to slips of 40 per cent., when the falling-off of both thrust and torque became serious. The same statement applies to the results at the higher speed up to slips of 24 per cent., the limit of the experiments. The variation in torque as each wave passed was 8 per cent. to 16 per cent., the higher percentage applying to the smaller torques. In overtaking waves of the same height, the variation in torque was 10 per cent. to 16 per cent. at and above 40 per cent. slip, the thrust gradually falling off above this slip. When meeting waves it was difficult to get a stable record at slips much above 40 per cent. Up to this slip the variation was about the same as in overtaking waves, but the screw thrust and torque were inclined to break down, due to air entering the screw at high slips and passing more or less round the disc. This can be seen from Fig. 2 which shows a torque diagram first in still water, then meeting waves with no air passing round the propeller disc, and meeting waves with air breaking into the disc. In overtaking waves, the same sort of trouble was found, but the slip could be increased to about 48 per cent. before it was quite so bad as when meeting the same waves at 40 per cent. slip.

11. At the lighter immersion, *i.e.*, with centre immersed 0·55 diameter, speed 217 ft. per minute in still water, the curve of $\frac{\text{thrust}}{(\text{velocity})^2}$ was falling off rapidly at 40 per cent. slip, and it was not possible to develop a thrust above about 11·5 lb. This could only be maintained fortuitously, as the air ultimately entered the disc and thrust dropped considerably. When meeting waves 6 in. high (0·75 diameter) the thrust broke down at 40 per cent. slip, air then passing right round the disc. The thrust was then 5 lb., and although higher thrusts up to 6·9 lb. were measured, they could not be maintained, 5·5 lb. to 6 lb. being about the limit. Below 40 per cent. slip, the variation in torque as each wave passed was about the same as at the deeper immersion, but with air entering the propeller the variation was roughly 50 per cent. as each wave passed, and the breakdown occurred. It should be noted that in this condition the immersion of the centre of the screw disc was varying from about 0·9 to 0·17 diameter. In overtaking waves the breakdown occurred at about the same slip and with about the same thrust, but the variation was not quite so serious, being about 30 per cent. at 40 per cent. slip. The small falling-off in thrust and efficiency in waves with small immersion of the blade-tips and moderate slips, the very large falling-off in thrust with greater emersion or large thrusts, and the not very great drop in efficiency are in general agreement with the results at varying immersions in still water. The latter results can be accepted in a general way, therefore, as indicating what occurs with ship screws when the ship is pitching. There appears to be a limiting thrust for satisfactory working with the blade-tips partially emerged, the thrust depending on the immersion and the diameter of the screw.

12. It may be of interest to give here the results of some recent observations of the torque on a steam trial of a single-screw ship. With the screw tip some 2 ft. out of water, or about one-eighth the diameter emerged and no pitching, the variation of torque taken over a prolonged period was 4 per cent. With the vessel pitching in waves so that the variation of immersion was about 4 ft. to 5 ft. (the blade-tips usually going completely under water at each pitch), the average variation in torque was 6 per cent., and varied occasionally to 12 per cent., the variations taking place in a fairly regular manner with each pitch. The vessel had fairly fine lines, and the slip of the screw was roughly 30 per cent.

13. *Screws behind Model at Varying Immersion.*—A number of single-screw models have been run at different times, with screw propeller behind, and occasionally experiments have been made at two immersions. When analysed on lines laid down by Froude, the results for load conditions show in general :—

(*a*) A thrust deduction fraction increasing slowly with fullness of form, and a wake fraction increasing much more rapidly with fullness, so that hull efficiency steadily increases with fullness.

(*b*) The thrust deduction and wake fraction are independent of minor alterations of blade area, independent of pitch for quite fair variations, but vary with the rake back of the blade tips, both decreasing as rake is increased. As a check upon this general conclusion as regards pitch, a model of 0·76 prismatic coefficient has recently been tested with the two propellers F2 and Q of Table I. These have the same area, diameter and rake, but differ in pitch ratio. The thrust deduction fractions were precisely the same (0·2), the wake fractions were 0·36 and 0·35 with F and Q respectively. When propeller H2 was used behind the same model the thrust deduction fraction was 0·15 and the wake fraction 0·28. The centres of bosses were in the same fore and aft position in all cases, but the rake aft of H2 was abnormally large compared with that of Q, which had about the same pitch ratio.

(*c*) When through any cause the resistance to be overcome by the propeller is increased, the thrust deduction increases, 30 per cent. increase in resistance causing 4 per cent. increase in thrust deduction for the model mentioned in (*b*), and the wake fraction drops roughly 3 per cent. for the same resistance variation, *i.e.*, a total loss on efficiency of 7 per cent. accompanying the 30 per cent. increase in resistance. These variations were practically the same with all three propellers.

(*d*) In ballast condition, with twin-screw ships, the thrust deduction and wake fractions are practically the same as for deep load. Such vessels are usually fine-lined, and the propellers are well immersed in any case. But with a single screw the propeller tips are well through the water in ballast condition. As the ship is lightened the thrust deduction fraction drops, and the wake after a little uncertain variation at first drops, and then rises rapidly. Table III shows results obtained with a model of 0·736 prismatic coefficient.

TABLE III.—*Effect of Immersion on Wake and Thrust Deduction Fractions.*

Immersion of screw centre in terms of diameter ..	0·92	0·69	0·41	0·31	0·00
Model wake fractions ..	0·45	0·49	0·45	0·31	0·07
Model thrust deduction fractions	0·25	0·24	0·21	0·18	0·12

14. These results were rather disturbing, as it was hardly possible to believe that the true wake fraction was higher in the ballast condition than it was in the load condition. Experiments have therefore been made with the object of studying these wakes. A model of 0·79 prismatic coefficient with a fair amount of eddy-making aft was tested at loaded draught with a propeller 9·75 in. diameter (0·78 of draught), 11·5 in. face pitch, at immersion of centre equal to 0·71 diameter at a speed corresponding to 13·8 knots for a 400-ft. ship. Seven fore and aft positions of the propeller were tried, and the wake and thrust deduction fractions obtained are given in Table IV.

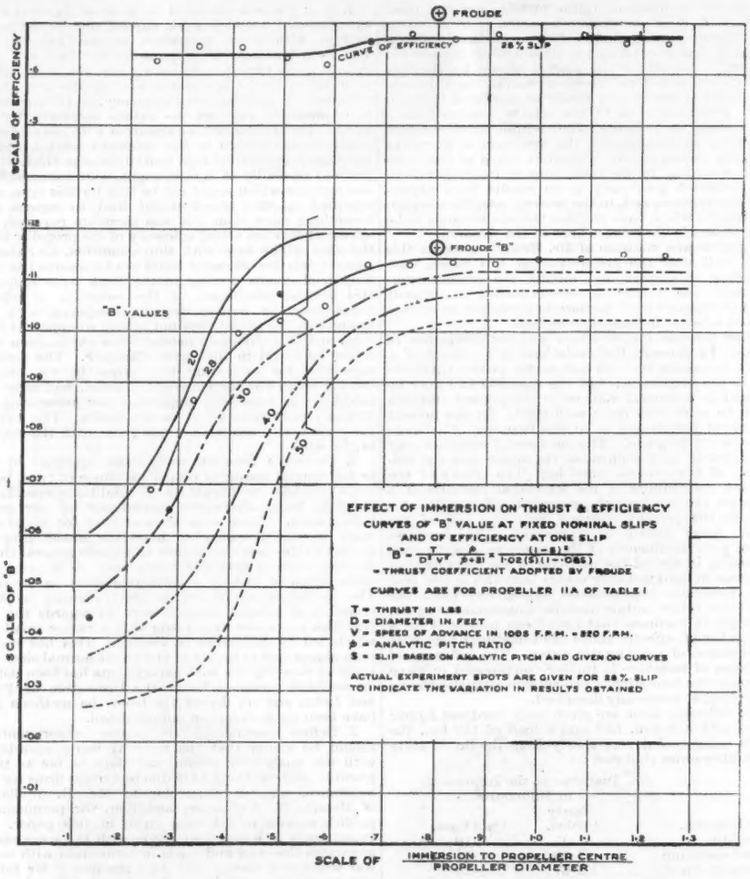

FROUDE
CURVE OF EFFICIENCY
28% SLIP
FROUDE "B"
"B" VALUES
20
28
30
40
50
EFFECT OF IMMERSION ON THRUST & EFFICIENCY
CURVES OF "B" VALUE AT FIXED NOMINAL SLIPS
AND OF EFFICIENCY AT ONE SLIP
"B" = p/D √(V²/T) = (1−s)³ / √(2(s)(1−·085))
= THRUST COEFFICIENT ADOPTED BY FROUDE
CURVES ARE FOR PROPELLER 11A OF TABLE I
T = THRUST IN LBS
D = DIAMETER IN FEET
V = SPEED OF ADVANCE IN 1005 F.P.M. = 820 F.P.M.
p = ANALYTIC PITCH RATIO
s = SLIP BASED ON ANALYTIC PITCH AND GIVEN ON CURVES
ACTUAL EXPERIMENT SPOTS ARE GIVEN FOR 28% SLIP
TO INDICATE THE VARIATION IN RESULTS OBTAINED
SCALE OF EFFICIENCY
SCALE OF "B"
SCALE OF IMMERSION TO PROPELLER CENTRE / PROPELLER DIAMETER

FIG. 1.

TABLE IV.—*Effect of Fore and Aft Position of Screw on Wake and Thrust Deduction Fractions.*

Propeller Abaft its Normal* Position, in Terms of Diameter.	Thrust Deduction Fraction.	Wake Fraction (*w*). As Obtained.	Wake Fraction (*w*). Modified Close Up (see Para. 14).	Hull Efficiency (*h*). As Obtained.	Hull Efficiency (*h*). Modified as per Para. 14.
Nil	0·31	0·69	0·66	1·17	1·15
0·1025	0·27	0·68	0·63	1·23	1·19
0·205	0·24	0·67	0·60	1·27	1·22
0·308	0·21	0·65	0·57	1·30	1·24
0·718 A	0·14	0·46	—	1·25	1·25
1·025	0·11	0·39	—	1·24	1·24
2·2	0·03	0·14	—	1·10	1·10

* Normal position is 0·205 diameter aft of body post.

When close up to the hull the propeller works in streams which, as they come from forward, are converging inwards and moving up from the keel. But this motion has largely ceased several inches aft from the model, and the hull efficiency elements should then be free from any effect due to this cause. With movement aft, the thrust deduction drops quickly at first and then slowly. The wake fraction remains almost steady at first, shows a

marked drop at A, Table IV, col. 1, and then drops slowly and continuously. If the general variation of wake a little aft the model is taken to indicate the proper variation close up to the hull, clear of any interference from cross-flow or convergence of streams, the values of w and h are as given in the table.

15. Taylor has recently published results of tests bearing a resemblance to the above, which may be usefully quoted here. His experiments were made with a 20-ft. model of prismatic coefficient 0·769, with three propellers varying in diameter from 8·7 in. to 10·8 in., whose fore and aft positions were varied. The shaft axes were arranged at two depths, the tips of the propellers being always well covered with water, the minimum cover being 0·07 diameter. The mean of the results at the two depths is given in Table V.

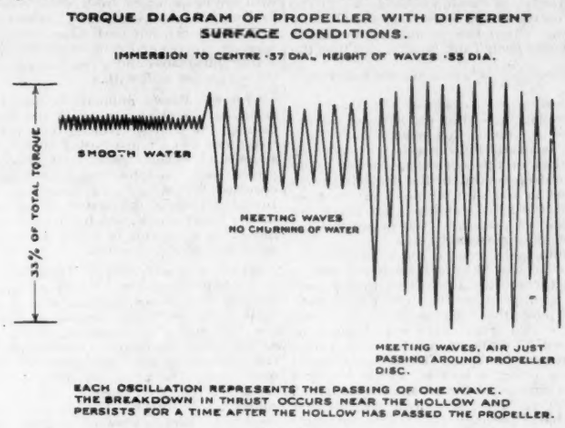

TORQUE DIAGRAM OF PROPELLER WITH DIFFERENT SURFACE CONDITIONS.
IMMERSION TO CENTRE ·57 DIA. HEIGHT OF WAVES ·55 DIA.
33⅓% OF TOTAL TORQUE
SMOOTH WATER
MEETING WAVES NO CHURNING OF WATER
MEETING WAVES, AIR JUST PASSING AROUND PROPELLER DISC.
EACH OSCILLATION REPRESENTS THE PASSING OF ONE WAVE. THE BREAKDOWN IN THRUST OCCURS NEAR THE HOLLOW AND PERSISTS FOR A TIME AFTER THE HOLLOW HAS PASSED THE PROPELLER.

FIG. 2.

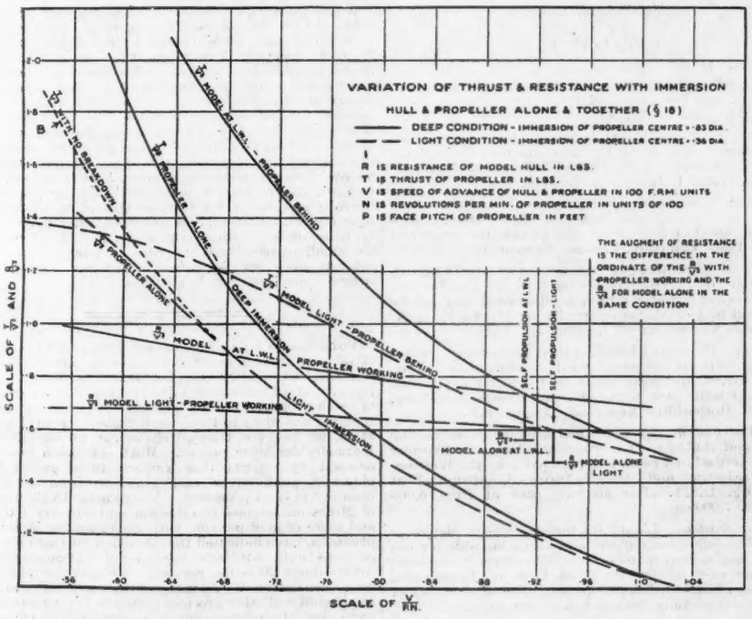

VARIATION OF THRUST & RESISTANCE WITH IMMERSION
HULL & PROPELLER ALONE & TOGETHER (§ 18)
DEEP CONDITION - IMMERSION OF PROPELLER CENTRE ·83 DIA.
LIGHT CONDITION - IMMERSION OF PROPELLER CENTRE ·36 DIA
R IS RESISTANCE OF MODEL HULL IN LBS.
T IS THRUST OF PROPELLER IN LBS.
V IS SPEED OF ADVANCE OF HULL & PROPELLER IN 100 F.P.M. UNITS
N IS REVOLUTIONS PER MIN. OF PROPELLER IN UNITS OF 100
P IS FACE PITCH OF PROPELLER IN FEET
THE AUGMENT OF RESISTANCE IS THE DIFFERENCE IN THE ORDINATE OF THE T/V² WITH PROPELLER WORKING AND THE R/V² FOR MODEL ALONE IN THE SAME CONDITION
SCALE OF R/V² AND T/V²
SCALE OF V/PN
MODEL AT L.W.L. - PROPELLER BEHIND
PROPELLER ALONE
MODEL LIGHT - PROPELLER BEHIND
DEEP IMMERSION
MODEL AT L.W.L. - PROPELLER WORKING
MODEL LIGHT - PROPELLER WORKING
LIGHT IMMERSION
SELF PROPULSION AT L.W.L.
SELF PROPULSION - LIGHT
MODEL ALONE AT L.W.L.
MODEL ALONE LIGHT

FIG. 3.

TABLE V.—*Effect of Fore and Aft Position of Screw on Wake and Thrust Deduction Fractions.*

Mean of Taylor's Results.

Propeller Abaft its Normal* Position in Terms of Diameter.	Thrust Deduction Fraction.	Wake Fraction.	Hull Efficiency.
	t.	w.	h.
0·06	0·32	0·55	1·05
0·195	0·266	0·43	1·05
0·495	0·20	0·315	1·05

* The normal position has been taken as 0·205 ft. abaft stern contour to compare with Table IV.

The propellers chosen by Taylor were small in order that they could be moved vertically and still be kept submerged. As a consequence the w and t results are a little higher than would be obtained with a screw of normal dimensions. There is the same increase in both as is done in Table IV, and that the results then obtained would be nearer the truth. Except for these cases, therefore, the results agree with Froude's conclusions based on faster ships

17. An endeavour to measure the effect of the elimination of eddy-making upon the quasi-propulsive coefficient has been made on a model of 0·75 prismatic coefficient. In its original form there was a fair amount of eddy resistance for this model, and when modified by fining the stern a little (recovering the displacement lost in other parts of the hull) the resistance dropped 6 per cent. Both models were tried with a single propeller in both deep and light condition (screw tips just immersed in the latter). In the light condition the quasi-propulsive coefficient was practically the same in both forms. In the deep condition there was a 4 per cent. improvement, partly due to improved thrust deduction, and partly to improved screw efficiency. The eddy-making in this model was mostly on the higher levels.

In a second case, again with a model having fairly marked eddy-making at the stern, the normal screw propeller with small rake was replaced by one with large rake (H2 of Table I). The model was tested both light and deep. The screw with large rake showed a 4 per cent. improvement in quasi-propulsive efficiency, but when the small rake screw was shifted aft, so that its blade tips worked in the same position as did those of the screw with large rake, this difference disappeared. The large rake screw was working in better water.

A similar set of experiments with a somewhat better model, *i.e.*, with less eddy formation, showed little or no effect from alteration of rake. In the light condition, the quasi-propulsive coefficient with the screw of large rake was 2 per cent. or 3 per cent. worse than that with the screw of small rake. But in both these models the large rake screw showed one rather valuable characteristic. The breakdown in $\frac{T}{V^2}$ behind the model, shown in Fig. 3 for light condition, occurred at much higher slips, and was much less emphatic with the large than with the small rake. Further experiments are desirable on this matter, but it would appear that (*a*) air entering the disc at the propeller tips, finds it more difficult to pass to the propeller centre when this is up stream; (*b*) the rake of the propeller distributes the acceleration produced in the surface streams over a greater fore and aft distance, with consequent smaller gradients of pressure and therefore less tendency to breakdown. This higher attainable pressure would have an important effect in maintaining speed in heavy weather in ballast condition (see Section 20 (*d*)). It appears, therefore, that with really full boats a good rake is desirable for good efficiency, and in heavy weather it appears to possess advantages over the screw with no rake.

18. With regard to the very high wakes in the ballast condition, these are based on a number of assumptions involved in Froude's method of analysis, and the data obtained require examination to see if these assumptions are justified. Fig. 3 represents a normal set of curves of $\frac{\text{thrust}}{(\text{velocity})^2}\left(\frac{T}{V^2}\right)$ to a base of $\frac{\text{velocity}}{\text{pitch} \times \text{revolutions}}$, for light and load condition. The velocity used in working out the ordinates and abscisse for screw behind model, is the velocity of the model, and for screw in open water is its actual velocity, the latter being less than that of model, to give results in open water at about the velocity existing at the stern of the model. The curve of $\frac{T}{V^2}$ behind slowly falls away from a parabolic curve and ultimately flattens out, and in some cases drops as slip is increased. The $\frac{T}{V^2}$ curve in open water at ballast immersion is showing a falling off in value at about 35 per cent. slip. The two curves cross each other at about 40 per cent. slip. In other words, at an apparent slip of 40 per cent. behind the model and a real slip of 40 per cent. in the open, the screw is producing the same value of $\frac{T}{V^2}$. If the conditions in the open water are representative of those behind the model, the apparent must be the real slip behind the model, and the wake fraction is therefore zero. On the other hand, at smaller slips behind, the wake fractions required are very high. Thus at $\frac{V}{PN} = 0{\cdot}92$, $\frac{T}{V^2}$ behind $= 0{\cdot}62$. If the wake fraction is 0·68, the real values become $\frac{V}{PN} = 0{\cdot}548$ and $\frac{T}{V^2} = 1{\cdot}75$, which brings it on the open screw curve at B, if the open curve is assumed not to break down. It seems fairly clear that such large variations of wake are not genuine. In the deep condition there is some such variation, but not to any considerable extent, and Mr. Froude met with the same variation, as he states (Trans. I.N.A., 1883), "the thrust behind in many cases is somewhat less steep than that which would agree with the open curve at all slips, indicating a wake fraction diminishing slightly with thrust." At the time he attributed this to the extent of the wake water dealt with, varying with thrust, so that the value of its means effective speed will increase or decrease as thrust increases or decreases, according as the speed of the surrounding zones of water is greater or less than that over the disc area. If this effect were material it would involve different curves of $\frac{T}{V^2}$ behind the model at different ship speeds, and in the deep condition we do not find any material change in this respect, except at quite high slips.

19. A detail examination of the thrust of a model propeller in open water, shows that if this thrust is represented by a formula

$$T = a N^2 - b N$$

the values of a and b remain quite constant in the deep condition, but vary very greatly in the light condition, the variation depending on the slip. Table VI gives the values of a and b at slips about 5 per cent. and 30 per cent. In the former case the $\frac{b}{a}$ ratio remains quite constant, and a decreases with emersion, but not quite so fast as does the immersed disc area. At 30 per cent. slip $\frac{b}{a}$ falls continuously with emersion, and a falls in a different manner to what it does at small slips.

The virtual pitch of the screw is given by the term $\frac{V}{D}\frac{a}{b}$, and the fall in $\frac{b}{a}$ must therefore mean a steady increase in virtual pitch or a fall in velocity, *i.e.*, the intake velocity at the screw disc falls off as the screw emerges from the water. The falling off in a value means that less thrust is exerted, and when a falls (as it does at working slips) at a greater rate than the area diminishes, it must mean a smaller pressure per unit area, and therefore less work done on the water per unit area, which accords with a fall in intake velocity at right angles to the disc. A propeller in open water, with its axis 5 deg.

to the direction of motion, gave a $\frac{T}{V^2}$ curve which, compared with the $\frac{T}{V^2}$ for the propeller with axis fore and aft, had a wake fraction of about 4 per cent. at all slips. Cross flow set up behind a hull by the unequal and varying thrust above and below the axis, might easily account for such a variation at the disc, and be answerable for some of the apparent wake, especially in light condition.

TABLE VI.—*Variation of Thrust Characteristic with Immersion.*

Screw Diameter, 9·75. *Face Pitch Ratio*, 1·06.

Immersion of Centre of Screw in Terms of Diameter.	30 per Cent. Slip.				5 per Cent. Slip.			
	a	b	$\frac{b}{a}$	$\frac{V}{PN_0}$	a	b	$\frac{b}{a}$	$\frac{V}{PN_0}$
0·615	1·16	2·62	225	1·03	0·96	2·19	227	1·026
0·513	1·12	2·50	223	1·04	0·96	2·19	227	1·026
0·41	0·92	1·98	216	1·08	0·93	2·12	222	1·026
0·31	0·83	1·80	215	1·08	0·86	1·95	227	1·026
0·20	0·62	1·26	203	1·15	0·74	1·69	227	1·026
0·0	0·38	0·70	183	1·27	0·63	1·44	227	1·026

The falling off in thrust and velocity is essentially a surface characteristic, and depends at any immersion more on thrust than on slip, and it will appear with screws behind the model as in the open, when the blades near the surface are experiencing about the same thrust per unit area. With the high wake velocity existing at the surface behind the model, the thrust here will be reached quite early on the slip base, with consequent falling off of a and $\frac{b}{a}$, and this causes the curve of $\frac{T}{V^2}$ behind to be generally flatter than in the open. The difference at different slips is not a true wake difference, as owing to the screw being differently affected in both a and $\frac{b}{a}$ by the surface, the thrust curve in open water has not necessarily any application to the conditions behind the model. For this reason it appears that the high w values obtained under these conditions cannot be accepted as genuine. As support to this, reference may be made again to Taylor's recent wake work. The measured wake fraction with a small screw behind the lower levels of a model of 0·769 prismatic coefficient, when the model was down at its L.W.L., was 0·30, at the normal distance aft the body post, but for a similar model in the tank at light draught, when the screw would be at the surface, the wake found would be double this in value.

20. In view of these results and considerations for the ballast condition, attention is chiefly centred on the quasi-propulsive coefficient, i.e., the ratio

$$\frac{\text{Effective horse-power for ship}}{\text{Power put into propeller to propel ship}}$$

This is independent of what wake fraction may be assumed, as the denominator depends solely on the revolutions and torque in the shaft. For single-screw ships it is usually found to improve a little in the light condition partly due to better slip conditions, but probably to better supply of water.

21. *Application of Model Results to Ship.*—In reporting upon screw propeller tests, the model data as regards thrust deduction fraction and quasi-propulsive coefficient, have been put forward as applying to the ship. The wake fractions are also given, but with an expression of opinion in some cases where very disturbed motion is obtained, that these wakes are not very exact and probably higher than in the ship. For the ballast condition, wakes are not now given. This procedure is based on the following arguments.

(*a*) The augment of resistance (on which the thrust deduction fraction depends) is due to the effect of the applied propeller pressure on the stream lines in front of it and at the rear of the ship. The propeller, hull form, and relative positions of one to the other are the same in ship and model, and ignoring viscosity, the effect produced by a thrust which varied with (dimensions)^3 would be the same in both ship and model. This condition is achieved at the same true slip in both cases. The energy lost in producing forward motion in the friction belt is relatively less in the ship than in the model, and the dispersal of this belt and its energy in the wake water may mean a slightly smaller slip for self-propulsion in the ship than in the model. But the experiments show that quite moderate changes in slip have only a small effect on the thrust deduction, and that this effect can therefore be ignored.

(*b*) Adopting the same quasi-propulsive coefficient for ship and model, assumes that the reaction between the form and propeller, and the screw efficiency of propeller behind the form, are the same in both cases. The reaction has already been considered, and the screw efficiency is the only doubtful matter. Underlying all Tank work is the assumption that the character of the flow at the stern of the model is the same as in the ship. There are definite theoretical grounds for asserting this is true both for a non-viscous fluid, and in the case of eddy formation, provided the formation of the eddies involves a resistance varying as (speed)^2. The skin friction, as already stated, may have the effect of reducing the necessary slip for ship. This reduction will not be so much as might be supposed, as the excess of resistance in the model, due to its high skin friction resistance, is replaced in the ship to some extent by appendage, wind, and wave resistance. If the slip is smaller in the ship, with all ordinary single-screw ships it would mean a slight improvement in efficiency. The present tank practice of ignoring this is considered the wiser course, as it is always better to be pessimistic in the design stage, leaving optimism for the trials.

(*c*) Comparisons of results with single-screw ship trials, although not very conclusive, have shown (1) that generally the ship wake is lower than in model, the maximum difference so far found being a ship $w = 0·4$ and a model $w = 0·6$; (2) that the powers estimated from the model and its propeller are reasonably close to those obtained on measured mile trials, and show no definite departure in any definite direction. A Tank paper recently read before the North-East Coast Institution of Engineers and Shipbuilders should be read on this subject.

(*d*) When the propeller tips are well out of water the effect of the free surface upon the ship screw appears to be different from that on the model screw. The analysis of several ship trials shows that the revolutions are higher than would be predicted from Tank results, and that the thrust obtained at given $\frac{V}{PN}$ is lower. This is believed to be due to the relatively greater ease with which air may penetrate the water with the ship propeller or to the disturbed sea surface facilitating this in some way. It is mentioned here only as an additional reason for suspecting that the model wakes in this condition do not apply to the ship. In the deep condition, the predicted revolutions have checked in the ship within 2 per cent. or 3 per cent., but in the light condition the maximum discrepancy has been 18 per cent., the propulsive coefficient, however, coming reasonably close.

(*e*) The thrust obtainable from a screw propeller is limited by its emersion and slip, and when the ship is pitching, the mean thrust falls away from that in still water towards that appropriate to the smaller immersion during a pitch. Under these conditions only broad conclusions can be drawn from model experiments, as the churning effect will be different in model and in ship, and start at different relative slips. The speed attainable by the ship at any draught is that which produces balance between this diminished thrust, and the total hull, sea and wind resistance. This, of course, assumes that the engines are capable of developing the torque necessary to maintain this thrust.

CATALOGUES.

Electric Motors.—The current list of motors and dynamos held in stock by the A.C.E. Company, of Charleroi, has been received from their London office, 56, Victoria-street, S.W.

Steam Fittings.—A catalogue of injectors, valves, cocks, forced sight-feed oil pumps and metallic packing, has been received from Messrs. Green and Boulding, Limited, 162A, Dalston-lane, London, E.

Electric Wiring.—A catalogue describing their wiring system and giving particulars of the necessary wire and fittings, has come from the British Insulated and Helsby Cable Company, Limited, Prescot, Lancashire.

Braiding Machine.—A machine for the braiding operations of covering cables and wires, and for the production of tubular fabric, is illustrated and briefly described in a catalogue received from Mr. O. N. Beck, 11, Queen Victoria-street, London, E.C.

Paints.—Circulars describing their preparations, which include ordinary paints, wood preservatives, stone preservatives, and a special stone liquid for application to damp walls, are to hand from Messrs. Szerelmey, Limited, Rotherhithe New-road, London, S.E.

Oil Purification.—A centrifugal machine for extracting water and sludge from lubricating oil and transformer oil is described in a catalogue received from the Westinghouse Electric and Manufacturing Company, East Pittsburg, U.S.A. The machine runs at from 6,000 r.p.m. to 7,000 r.p.m.

Motor Starters.—Liquid starters for use in the rotor circuits of induction motors, and also adaptable for use with direct-current motors, form the subject of a special catalogue received from the Brush Electrical Engineering Company, Limited, Loughborough. The applications of the starters are fully described in the catalogue.

Counting Apparatus.—A catalogue of 80 pages, describing the many varieties and adaptations of the well-known counting devices made by the Veeder Manufacturing Company, 80, Sargeant-street, Hartford, Connecticut, U.S.A., has been received from their agents, Messrs. Markt and Co., Limited, 98, Clerkenwell-road, London, E.C.

Protective Paint.—The bituminous solution made by Messrs. William Briggs and Sons, Limited, Dundee, and 6, Lloyd's-avenue, London, E.C. 3, has been adopted for use on the Forth, Tay, Wear, Barrow (Waterford) and other large bridges. The firm have recently issued a booklet drawing attention to this fact and giving illustrations of the bridges.

Motor Boats.—Motor launches and cabin boats up to 120 ft. in length are illustrated in the catalogue issued by Messrs. S. E. Saunders, Limited, East Cowes, Isle of Wight. Among them are included high-speed racing boats, as well as the more comfortable pleasure craft for lower speeds. The firm also make removable engines, developing 2½ h.p. and 5 h.p., for fitting into small boats.

Oil Cans.—Many useful and convenient shapes of hand oil cans, as well as tanks, pumps and other fittings for storing and filling oil are dealt with in an illustrated priced list received from Messrs. Joseph Kaye and Sons, Limited, 93, High Holborn, London, W.C. Much ingenuity is incorporated in the designs of these appliances to meet the convenience of users in all classes of work.

Grinding Spindles.—An excellent series of grinding spindles, designed for mounting on the slide rest of lathes, is dealt with in a catalogue received from the Productive British Grinders, Limited, Mossley-street, Birmingham. The spindles are driven by belt either from an overhead shaft or from a small motor attached to the slide by a special bracket. The grinding wheels range from 12 in. to ¼ in. in diameter.

Steam Heating Apparatus, &c.—Apparatus for heating water by means of steam passing through Row's patent indented tubes is the principal subject of a catalogue received from Messrs. Royle's, Limited, Irlam near Manchester. Among the more prominent items dealt with are evaporators, fresh water condensers, calorifiers, feed-water heaters, steam and gas kettles, boiling batteries and air-heaters, but particulars are also given of all the necessary valves and connecting fittings. The catalogue is fully illustrated and gives dimensions and prices of all the apparatus dealt with.

Cranes.—Messrs. John H. Wilson, Dock-road, Birkenhead, have sent us a copy of the new edition of their catalogue of cranes. Among them are included portable steam cranes on four-wheeled bogies or gantries, as well as steam shovels, grabs and dredgers. Electrically-driven cranes supplied from overhead wires and others operated by storage batteries, are also dealt with. Included among the latter is one mounted on four rubber-tyred wheels, which can be steered about without rails, and is capable of lifting 15 cwt. at 10 ft. radius, or 10 cwt. at 12½ ft. radius.

Waterworks and Sewage Appliances.—Two large and very complete, and well produced, catalogues have been received from Messrs. J. Blakeborough and Sons, Limited, of Woodhouse Works, Brighouse, whose London offices are 199–201, High Holborn, W.C. 1. One of these catalogues is devoted to waterworks appliances, while the other deals with appliances for sewage works. In some items the two lists resemble one another since certain types, &c., suitable for one service, are also suited to the other. The waterworks list opens with reservoir outlet towers of several designs, and their fittings, including the arrangements for operating the valves. Fittings for smaller service reservoirs are then listed, these being followed by standpipes, floating outlet-arms, self-closing valves, filter regulators, sluice valves, both small and large operated by power, winches, hydraulic gear and standpipes, &c. Pipes and fittings, appliances for drilling, &c., under pressure, manholes, testing machines and sand washers, are also fully described and illustrated. The volume closes with a number of useful tables and an index. The volume devoted to sewage works appliances also lists standard valves and sluices of all sizes, winches or power mechanisms for operating the larger designs, flushing valves of several types, flap valves, floating outlets, weir gauges, mechanical screens and dredger elevators, sewage chain pumps, revolving and travelling distributors, lime mixers, manholes, and ironwork generally, flushing syphons, drain testing appliances, &c. Both volumes are small quarto, and one runs to over 440 and the other to over 200 pages, from which fact some idea of their completeness may be gathered.

POTASH AND RARE METALS FROM OIL SHALES.—Many oil shales contain small quantities of potash, but in few cases even after complete retorting—that is, after removal of all volatile and fixed carbon— is the amount of water-soluble potash enough to make recovery feasible, according to the United States Bureau of Mines. It is not believed that oil shales can be worked commercially for their potash. Much discussion has been aroused by reports that various investigators have obtained gold, silver and platinum from oil shales usually by secret processes. Assays made by the Bureau of Mines on samples of oil shale said to carry 1 ounce, and more of gold per ton, with corresponding silver and platinum, have indicated that although gold was present, it existed only as traces of the order of 0·01 ounce per ton worth about 20 cents. per ton. No silver or platinum have been detected. As many of those who claim to have found gold and other precious metals in paying quantities state that the metals cannot be detected or recovered unless they are "unlocked" by preliminary treatment, the Bureau made a series of tests and assays to determine the validity of these claims. Several of the tests were made in the presence of, and according to the methods said to be necessary by one of the private investigators who has received much publicity from his reputed discovery of methods of recovering precious metals from oil shales. A shale from which this investigator claimed he had recovered 7·50 dols. in gold per ton was used in the tests. Assays were made on the raw shale, spent shale, decarbonised shale, decarbonised shale treated with chlorine at temperatures most favourable for the formation of gold chloride, and on shale decomposed by chromic acid. All the assay returns checked closely, and indicated that the shale carried less than 65 cents. in gold. The fire assay return on the raw shale was the same as on the shale subjected to the various preliminary treatments. This work and similar assays by the Bureau of Mines, as well as other investigators, indicate little chance of gold and similar precious metals being commercially recoverable from oil shale. There is no particular reason why gold should occur in oil shale any more than it does in sea water, and although it is possible that small partings or fissures in the shales—not the shale itself—might carry notable quantities of these metals, it is not believed that shale will ever be a commercial source of gold, silver, platinum or allied metals.